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ORIGINAL ARTICLES.

I.—Notes on the Phylogeny of the Graptolites.

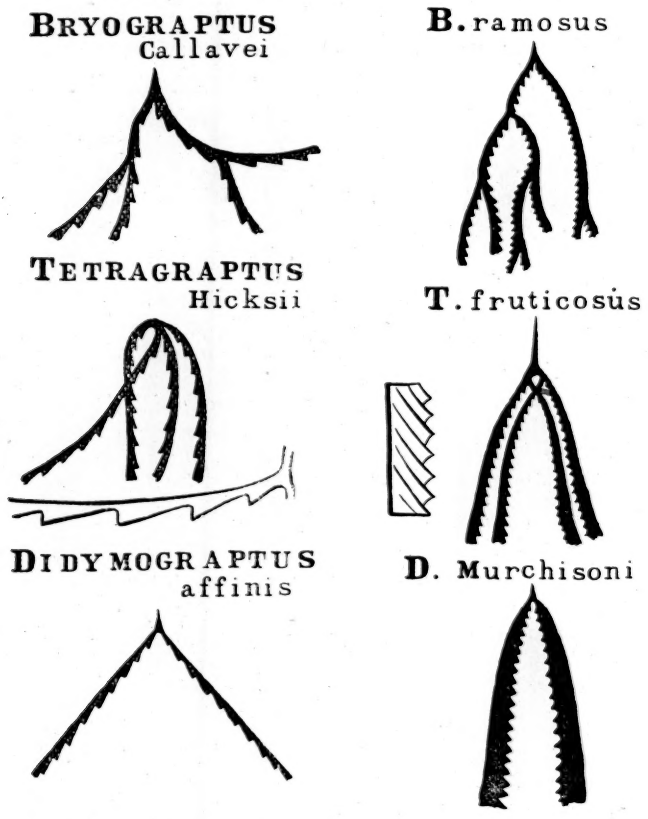
By Prof. H. A. Nicholson, M.D., D.Sc., and J. E. Marr, M.A., F.R.S.

SINCE the remarkable paper by Professor Lapworth "On an Improved Classification of the Rhabdophora" was published in the Geological Magazine for 1873, a great deal of fresh information has been gathered as to these interesting fossils; but the classification given in that paper, though to some extent confessedly artificial, is still generally adhered to. Observations made by the authors in recent years lead them to suppose that that classification will in the future undergo considerable modification; but in the present state of our knowledge it serves a purpose so useful, that it is not our intention to propose any immediate change in it. Our object, on the other hand, is to bring forward certain conclusions which we have independently reached, and which will, we believe, enhance the value of Graptolites to the stratigraphical geologist, and lead to results important to the biologist. Our conclusions are based upon an examination of a large number of forms generally referred to the family Dichograptidæ; but, as we propose very briefly to indicate, they affect the relationships of Graptolites belonging to other families also.

In general, the number of stipes possessed by Graptolites has been looked upon as a character of prime importance; indeed, many of the genera are based essentially on their possession of a certain number of stipes, as for example, *Loganograptus*, *Tetragraptus*, and *Didymograptus*. Again, the "angle of divergence" of the stipes has been considered an important factor in the diagnosis of families. As regards this latter point, however, the existence of a form like *Didymograptus gibberulus*, Nich., in which the angle of divergence is over 180°, whilst the other characters are those of a true *Didymograptus*, shows that this angle is not of primary importance in separating the major divisions of the sub-class Graptolitoidea. On the other hand, we have been led to believe that a character of really essential importance in dealing with the classification of the Graptolites, and one which, in all probability, indicates the true line of descent, is to be found in the shape and structure of the hydrothecæ.

In the more ancient types of Graptolites the hydrothecæ are comparatively simple, differing little from the initial sicula, except

in the fact that the proximal aperture gives connection with the cœnosarc.[1] Among these forms there are three more important types of hydrothecæ. In one group, the hydrothecæ are narrow and straight, the neighbouring cells barely overlapping, or not overlapping at all, while the aperture is straight, and is usually at right angles to the back of the stipe. In a second group, the hydrothecæ are also straight, but overlap to a marked extent, while the aperture is straight, and is at right angles to the back of the



stipe or at right angles to the hydrothecæ. In a third group, the hydrothecæ are curved, narrow at their bases and widening towards their mouths, while the aperture is curved, and its upper lip is usually prolonged into a pointed process or spine. In contrast with the comparatively simple hydrothecæ of the older types of Graptolites, we find later types, such as *Dicellograptus*, *Dicranograptus*, and more especially *Monograptus*, generally characterized by

[1] See Holm, Geol. Mag., Dec. IV, Vol. II, p. 435.

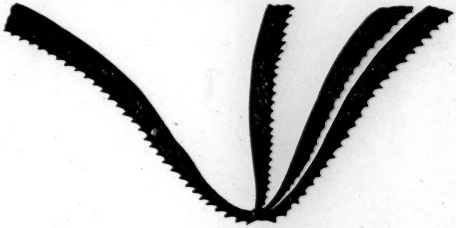
hydrothecæ which are much more complex, and which exhibit very marked modifications of the primitive sicula.

Taking the above facts into consideration, we find reason to conclude that the character of the hydrothecæ is the most important point to retain in view in separating different families of the Graptolitoidea. Taking any group of forms with hydrothecæ of a similar character, we believe that the next most important point to consider as indicating genetic relationship is the "angle of divergence." On the other hand, the number of stipes in the

Group 2.

Bryograptus retroflexus

Tetragraptus denticulatus

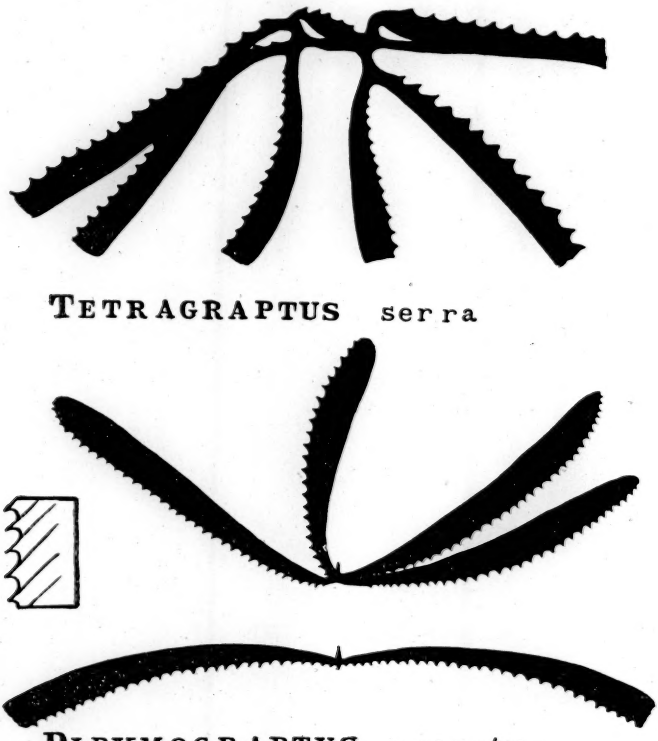


Didymograptus fasciculatus

polypary is a character of minor importance; since we think it can be shown that, separating Graptolites into groups characterized by their hydrothecæ, the different groups will in many cases exhibit a series of parallel modifications as regards the number of stipes in the polypary, the older forms of the group being the more complex, and the later forms undergoing reduction as regards this particular. Our views may be best illustrated by reference to forms belonging to the "genera" *Bryograptus*, *Dichograptus*, *Tetragraptus*, and *Didymograptus*, the appearance of which in time, in the above sequence, is indicated by stratigraphical observations.

In our illustrations we show nine species of *Tetragraptus*; and we are not acquainted with any others which have with certainty been referred to this genus, except *T. alatus*, Hall, which is only known from examples in very bad preservation. Eight of the *Tetragrapti* are represented by forms of *Didymograptus* which are closely comparable with them as regards the characters of the hydrothecæ and the amount of the angle of divergence; whilst the ninth (*Tetragraptus denticulatus*, Hall) is comparable with *Didymograptus*

Group 4.



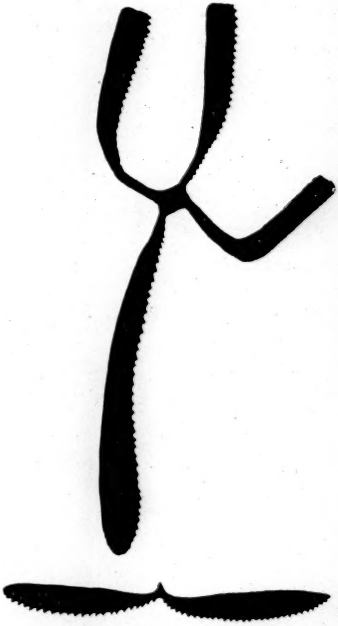
fasciculatus, Nich., as regards the angle of divergence, though the characters of the hydrothecæ of the two differ considerably in minor points. Moreover, four of these four-branched *Tetragrapti* are represented, as regards the characters of the hydrothecæ and the amount of the angle of divergence, by forms of *Dichograptus* or *Bryograptus*, with eight or more branches, and a fifth by a *Bryograptus* which agrees in the amount of the angle of divergence, though the hydrothecæ differ in minor points. Considering the amount of unworked material which we know to be in existence in

the case of the "genera" *Dichograptus* and *Bryograptus*, we confidently predict the discovery of forms of these or allied "genera" which will agree with the four remaining *Tetragrapti* as regards the above-mentioned characters.

Taking the series shown in our illustrations in order, we find the following points of agreement in the members of each group of the series, the chief or only points of difference being in the number of stipes in the polypary.

Group 7.

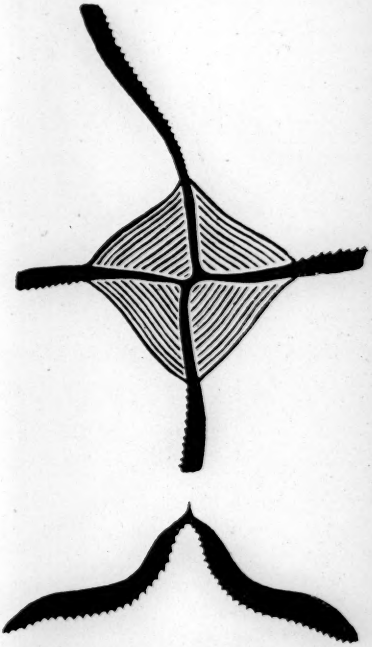
Tetragraptus
crucifer



Didymograptus
pennatulus

Group 5.

Tetragraptus
Headi



Didymograptus
V-fractus

(1) Group containing *Bryograptus Callavei*, Lapw., *Tetragraptus Hicksii*, Lapw. and Hopk., and *Didymograptus affinis*, Nich. In this group the stipes are narrow, and the hydrothecæ are of the rectangular straight type, and are in contact only or overlap very slightly; while the angle of divergence is about 90°. (This latter feature is not quite clear in the case of *Tetragraptus Hicksii*.) (See p. 530.)

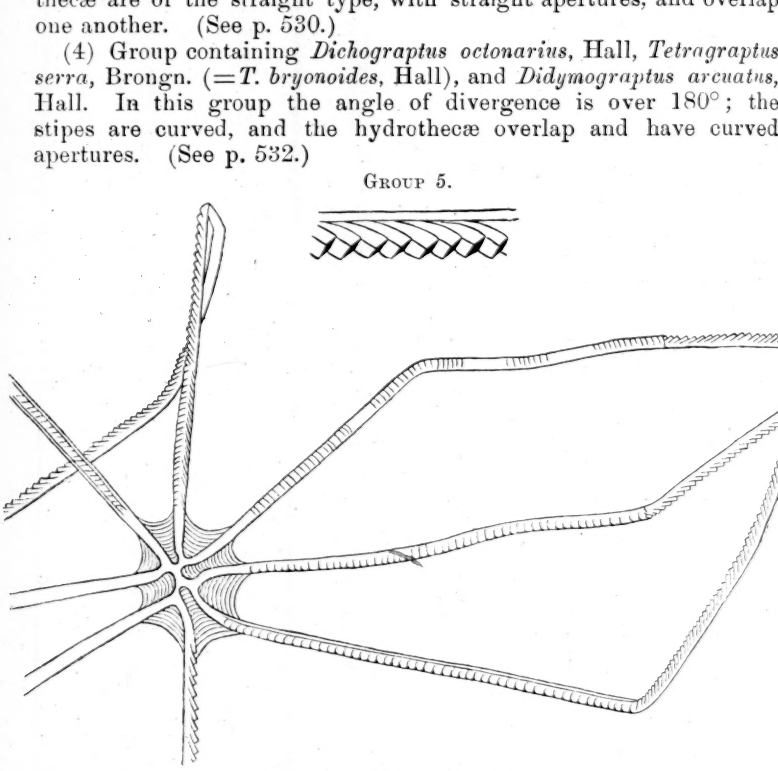
(2) Group containing *Bryograptus retroflexus*, Brögger, *Tetragraptus denticulatus*, Hall, and *Didymograptus fasciculatus*, Nich. In this group the angle of divergence is nearly 180° in the proximal

part of the polypary, the stipes curving backwards and then becoming straighter in the distal portion; while the hydrothecæ overlap, and are variable in form. (See p. 531.)

(3) Group containing *Bryograptus ramosus*, Brögger, *Tetragraptus fruticosus*, Hall, and *Didymograptus Murchisoni*, Boeck. In this group the angle of divergence is less than 45°, the stipes being sub-parallel in the distal portion of their course; while the hydrothecæ are of the straight type, with straight apertures, and overlap one another. (See p. 530.)

(4) Group containing *Dichograptus octonarius*, Hall, *Tetragraptus serra*, Brongn. (=*T. bryonoides*, Hall), and *Didymograptus arcuatus*, Hall. In this group the angle of divergence is over 180°; the stipes are curved, and the hydrothecæ overlap and have curved apertures. (See p. 532.)

Group 5.



Dichograptus octobrachiatus.

(5) Group containing *Dichograptus octobrachiatus*, Hall, and *D. Sedgwickii*, Salt., with *Tetragraptus Headi*, Hall, and *Didymograptus V-fractus*, Salt. In the forms of this group the stipes are very similar in character, all giving indications of the broken V-curve; while the hydrothecæ have straight apertures. (See also p. 533.)

(6) Group containing an unknown *Dichograptus*, *Tetragraptus Bigsbyi*, Hall, and *Didymograptus gibberulus*, Nich. (See p. 535.)

In this group the angle of divergence is over 180°; the stipes are broad and sub-parallel in the distal portion of the polypary; and the hydrothecæ are deep and curved, with curved, mucronate apertures. (See Nicholson, Ann. and Mag. Nat. Hist. 1875, p. 271.)

(7) Group containing an unknown *Dichograptus*, *Tetragraptus crucifer*, Hall, and *Didymograptus pennatulus*, Hall. (See p. 533.)
In this group the angle of divergence is at first less than 180°, but the stipes (in each pair of the *Tetragraptus*) are finally placed in the same straight line. The stipes are broad, and the hydrothecæ are inclined at a high angle to the line of the back of the stipe, and overlap one another.

(8) Group containing an unknown *Dichograptus*, *Tetragraptus quadribrachiatus*, Hall, and *Didymograptus extensus*, Hall. (See p. 536.) In this group the angle of divergence is under 180°, the stipes (of each pair in the *Tetragraptus*) are in the same straight line. The hydrothecæ are of the straight type, with straight cell-apertures.

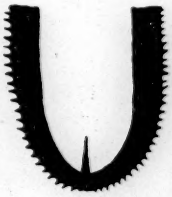
(9) Group containing an unknown *Dichograptus*, *Tetragraptus approximatus*, Nich., and *Didymograptus nitidus*, Hall. (See p. 537.) In this group the angle of divergence is under 180°; the stipes are curved in their proximal portion and afterwards placed in the same straight line (each pair in the case of the *Tetragraptus*). The stipes are narrow, and the hydrothecæ are of the straight type, with straight apertures.

Group 6.

TETRAGRAPTUS
Bigsbyi

Group 6.

DIDYMOGRAPTUS
gibberulus

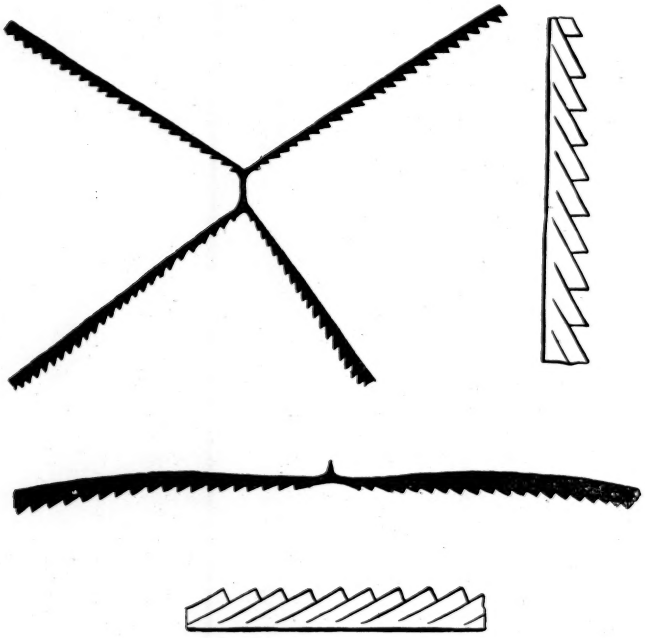


It must not be supposed that in all of the above-mentioned groups the nearest four-branched form to the corresponding eight-branched one, or the nearest two-branched form to the corresponding four-branched one, has been actually selected. For instance, in the case of the second group, the hydrothecæ of *Didymograptus fasciculatus*, Nich., are very different in some respects from those of *Tetragraptus denticulatus*, Hall, and *Bryograptus retroflexus*, Brögger. We believe, however, that in such cases other forms will ultimately be found which will remove this discrepancy. It is probable that a whole group of species sprang from an earlier form which possessed a greater number of branches than its descendants. Thus, the whole series of the "tuning-fork" *Didymograpti*—the *Murchisoni* group—is generally admitted to form one group, and we believe that all the species included in that group have sprung from *Tetragraptus fruticosus*, Hall. Many of the species of this group of *Didymograpti* agree much more closely with *Tetragraptus fruticosus* as regards the

characters of the hydrothecæ than does *D. Murchisoni*, and we have figured this latter simply because it is so well known. Again, it is quite conceivable that a *Didymograptus* which from its general shape would be placed in the *Murchisoni* group, might show hydrothecæ entirely different in character from those of *Tetragraptus fruticosus*, and might thus be shown to have descended from an altogether different type of *Tetragraptus*. That the *Didymograpti* were divisible into groups has long been known; and in 1885 Otto Hermann suggested (Die Graptolithenfamilie Dichograptidæ, Lapw.) six such groups, the types of these being respectively *Didymograptus patulus*,

Group 8.

TETRAGRAPTUS quadribrachiatus



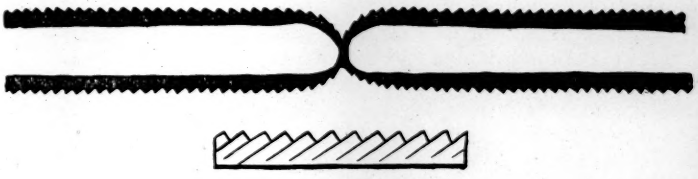
DIDYMOGRAPTUS extensus

Hall, *D. Murchisoni*, Boeck, *D. fasciculatus*, Nich., *D. pennatulus*, Hall, *D. affinis*, Nich., and *D.* V-*fractus*, Salt. Some of these groups, as before remarked in the case of the *Murchisoni* series, are certainly natural, while others will most likely be ultimately re-divided and will undergo a redistribution of their contained species. Each group, however, will probably be found to present close affinities to one particular species of *Tetragraptus*.

It is very difficult to understand how the extraordinary resemblances between the various species of *Tetragraptus* and *Didymograptus* have arisen, if, as usually supposed, all the species of these

genera have descended from a common ancestral form for each genus, in the one case four-branched, in the other case two-branched. On the other hand, it is comparatively easy to explain the more or less simultaneous existence of forms possessing the same number of stipes, but otherwise only distantly related, if we imagine them to be the result of the variation of a number of different ancestral types along similar lines. And, indeed, similar phenomena have been shown to exist in other groups of organisms. Thus, in a paper on "The Bajocian of the Mid-Cotteswolds," published in the Quarterly Journal of the Geological Society for August 1895, Mr. Buckman gives reasons for supposing that "genetic observations on Brachiopoda indicate that biplicate *Terebratulæ* are, at any rate in the Jurassic rocks, independent, or heterogenetic, homœomorphous derivatives of non-plicate forms. The method of nomenclature hitherto adopted rather tends, however, to confuse these biplicate forms

GROUP 9.



TETRAGRAPTUS approximatus

DIDYMOGRAPTUS nitidus

together, either as the same species, or as varieties of one another—and they are often difficult to distinguish—and totally overlooks their relationship to the non-plicate forms (from which they appear easily separable), thus ignoring their genetic affinities altogether." The same authority further remarks that "analogous cases of the heterogenetic development of similar but entirely unrelated forms are well known among Ammonites. Mojsisovics has called such cases, between non-contemporaneous Ammonites, 'heterochronous convergence.'" The conclusions which Buckman has reached as regards "species" of Brachiopods and Ammonites appear to us to be applicable to "genera" of Graptolites.

Following our inferences concerning the relative value of the form of the hydrothecæ and the amount of the angle of divergence to their legitimate conclusion, we may observe that when the angle of divergence reaches 360°, so that the stipes of the polypary coalesce by the whole of the dorsal surface, as in the members of the confessedly artificial families Diplograptidæ and Phyllograptidæ, the true relationships of the members of these "families" to one another

may be more remote than those to members of some other family. Thus, Hall (Grapt. Quebec Group, pl. xvi, fig. 26) figures a form of *Tetragraptus* which he refers to *T. Bigsbyi*,[1] in which the apices of the stipes are in contact, and remarks that "it is difficult to separate such forms from *Phyllograptus*." In fact, having examined many specimens, we are disposed to suggest that this form is truly intermediate between *Tetragrapti* of the *Bigsbyi* type and *Phyllograptus*.

Furthermore, as the unilateral *Monograpti* are related to the bilateral *Diplograpti* through *Dimorphograptus*, the same reasoning applies to these; and the single genus *Monograptus* may contain descendants of more than one "family." This would account for the great diversity in the character of the Monograptid hydrothecæ. Many *Monograpti* possess hydrothecæ resembling those of pre-existing Diplograptidæ, whilst one well-known species, *M. argutus*, has hydrothecæ closely similar to those of the family Dicranograptidæ.

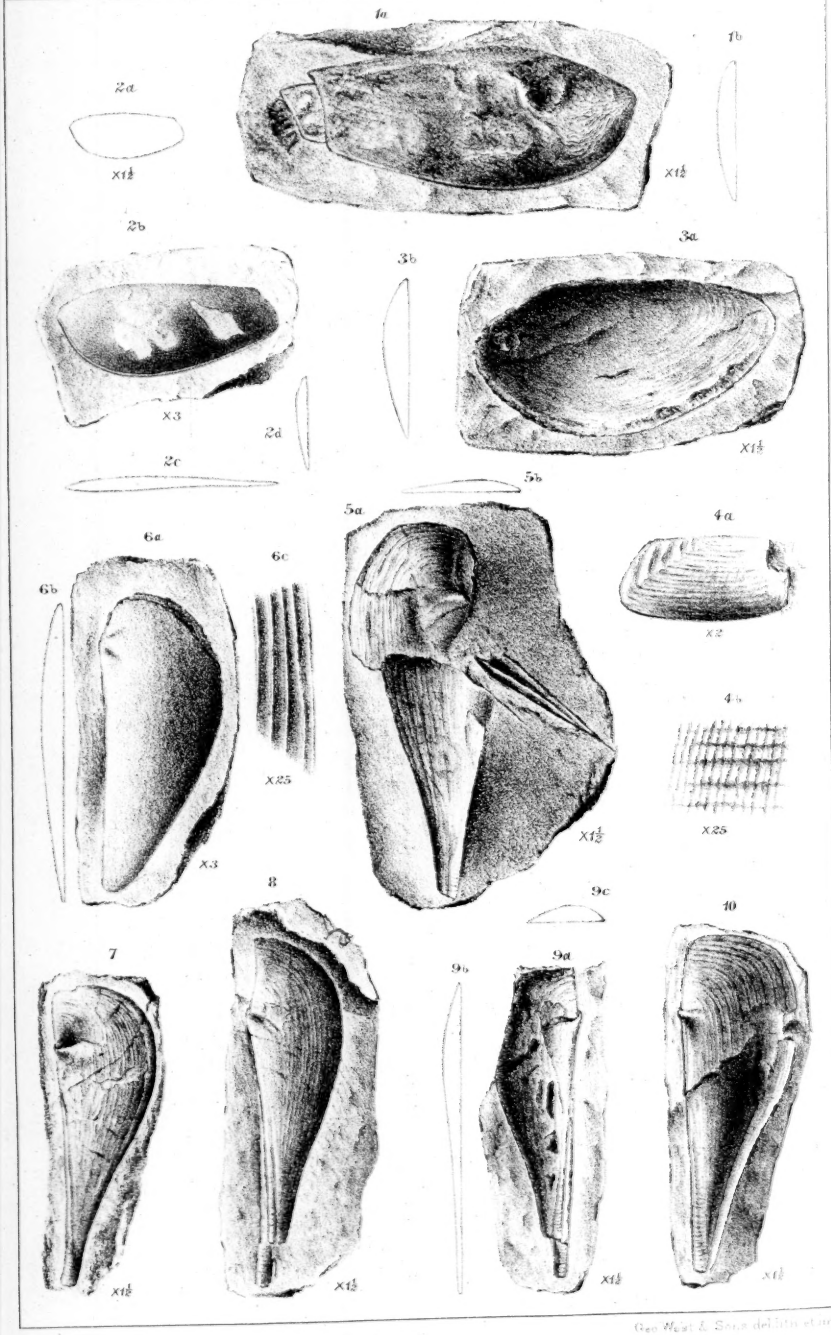
Should our conclusions be correct, the present nomenclature will have to be altered, for it is clear that two species of *Didymograptus*, to take an example, which have descended through different Tetragraptid forms, the one from a *Bryograptus*, the other from a *Dichograptus*, cannot be relegated to the same genus. In the present state of our knowledge we believe it would be not only inconvenient but also unpardonable to alter a classification the working value of which has been made fully apparent, and we propose, therefore, to retain such names as *Monograptus*, *Didymograptus*, and *Tetragraptus* as "generic" names, merely observing that we do not consider the species placed under these various groups to belong to definite genera, in the sense in which the word is used by biologists, but that they constitute cases of what Buckman terms heterogenetic homœomorphy of forms which are only distantly allied to one another.

To a considerable extent these homœomorphic forms are isochronous and not heterochronous, as proved by detailed work in the field; hence their extreme value to the stratigraphical geologist. They may be regarded as constituting a special case of mimicry, the reasons for the existence of which may be very briefly discussed.

We are indebted to Mr. Clement Reid for the first suggestion that the variations in the characters of Graptolites may be connected with the supply of food, and study of the variations inclines us to accept this suggestion as plausible, if not correct.

The earlier Graptolites (such as *Dictyograptus* in the Lingula flags, etc.) consisted of a number of irregularly-branching stipes; but symmetry in the arrangement of the stipes would tend to ensure an equal supply of food to each stipe; hence we soon meet (in the

[1] We have examined a large number of examples of the *Tetragraptus* here alluded to, which have been collected in the Skiddaw Slates of Troutbeck and Outerside, near Keswick, and are of opinion that it is specifically separable from *T. Bigsbyi*, Hall, and ought to receive a new name. Pending a complete description, we may therefore speak of this form as *T. inosculans*. In some of our specimens of this singular form not only are the apices of the stipes in contact, but more or less complete fusion or cohesion has taken place.



PALÆOZOIC PHYLLOPODS, &c.

Tremadoc rocks) with many-branched forms like *Clonograptus* possessing a symmetrical arrangement: the fewer the branches, however, the greater the supply of food to the entire organism; consequently we find forms with more than eight branches (*Loganograptus*) rapidly replaced by eight-branched forms (*Dichograptus*), these by four-branched forms (*Tetragraptus*), and these, again, by two-branched forms (*Didymograptus*). Professor Lapworth has privately furnished us with what is doubtless the reason why unilateral forms like *Azygograptus* did not survive, until the genus *Monograptus* became established in the Silurian rocks, but we await the publication of this reason. Four-branched forms descended from one series would be at a disadvantage as compared with two-branched forms of another; therefore, when once a two-branched form of one series was established, any departure from a four-branched to a two-branched form in another series would tend to survive, and the four-branched forms would die out, hence the general isochronism of forms belonging to diverse series possessing the same number of branches.

Again, forms having the series of hydrothecæ facing one another would receive a smaller supply of food than those having the hydrothecæ further apart; consequently the increase in the angle of divergence followed, which attained its maximum of 360° when the backs of the stipes came into contact with *Phyllograptus*, *Diplograptus*, and *Climacograptus*.

Lastly, hydrothecæ the openings of which faced downwards and lay in the same plane would be placed at a disadvantage compared with those which faced in different directions, hence the variations in the nature of the hydrothecæ resulting in the curved and sometimes twisted forms met with amongst the later Graptolites. This would also produce its effect upon the angle of divergence.

The above notes are offered as suggestions only, though in our opinion they are plausible. Should they be correct, the value of Graptolites, enormous as it already is to the stratigraphical geologist, will become equally so to the biologist; and we may look forward to the establishment of a complete phylogeny in the case of this remarkable sub-class.

II.—On some Palæozoic Phyllopoda.

By Professor T. Rupert Jones, F.R.S., and Dr. Henry Woodward, F.R.S.

(PLATE XV.)

1. Ceratiocaris reticosa, sp. nov. Plate XV, Figs. 1*a*, 1*b*.

In the Museum of Practical Geology there is a specimen of *Ceratiocaris* (No. 4435), from the vicinity of Ludlow, which was not noticed by us in the "Monograph of British Palæozoic Phyllocarida" (Palæontographical Society), 1888. It is a squeezed carapace, evidently allied to the *Ceratiocaris cassioides* there described and figured, pages 59–61, pl. iii, fig. 9; pl. iv, fig. 7; and pl. vii, figs. 4–6. The specimen appears to have been bivalved.

The contained animal matter has caused an irregular convexity (as seen also in figs. 4–6, pl. vii above mentioned), especially in the anterior third; and here it has been broken down, leaving a small rough cavity in some obscure organic material.

The exposed (right) valve has been damaged by pressure; but, though much excoriated, it retains on the lower part of the front moiety an ornament of numerous raised flexuous striæ (like those seen in fig. 9, pl. iii), trending upwards and forwards to converge at the anterior extremity. Near the postero-dorsal angle, moreover, there is a patch of peculiar reticulate sculpture, with lozenge-shaped meshes. Further trace of this ornament is visible for a little way towards the middle of the valve. In its proportions this specimen comes nearest to fig. 9 in pl. iii of the Monograph, but differs from it considerably; and still more from the other known examples. Thus:—

	Millimètres	
Length and height	29 × 12·50, specimen under notice, from near Ludlow.	Lower Ludlow formation.
,, ,,	26 × 11, the Monograph, pl. iii, fig. 9, p. 60, from Leintwardine, near Ludlow.	
,, ,,	25 × 14, the Monograph, pl. vii, fig. 6, p. 60, from Leintwardine, near Ludlow.	
,, ,,	25 × 12, the Monograph, pl. vii, fig. 5, p. 61, from near Ludlow.	
,, ,,	23 × 12, the Monograph, pl. vii, fig. 4, p. 60, from Tripleton, near Ludlow.	
,, ,,	22 × 12, the Monograph (not figured), p. 60, from Tripleton, near Ludlow.	
,, ,,	22 × 9, the Monograph, pl. iv, fig. 7, p. 60, from near Ludlow.	
(Not figured), the Monograph, p. 60, from Benson Knot, Kendal.		Upper Ludlow formation.

It has not nearly so great a height in its anterior moiety as *C. cassioides*; in consequence of its having a much less convex antero-ventral border. The sinuous striæ are comparable with those on both the front and hinder portions of fig. 9 in pl. iii; but none of the known examples exhibit the neat delicate reticulation, with lozenge-shaped meshes, which this additional example shows on its postero-dorsal area. Unfortunately only a limited patch remains, but the ornament is obscurely continued for a little way forwards towards the middle of the valve.

This peculiar ornamentation suffices to distinguish the species under consideration, even if the larger size and the more elongate or attenuate outline do not constitute a sufficient distinction.

2. Emmelezoe Lindstroemi, sp. nov. Plate XV, Figs. 2*a*–2*d*.

Several specimens, in a soft grey argillaceous limestone, homotaxial with the Wenlock Beds, from Lau, near the south-east coast of Gothland, Sweden, have been communicated by Professor Gustav Lindström, F.M.G.S. On one piece of this marly rock there are indications of at least six carapaces, flattened, and more or less mutilated by pressure, some showing a trace of the underlying

valve. Another specimen (shown by Fig. 2) lies alone on another piece of the same rock.

The enclosed animal matter expresses itself in the irregularity of the surface of the valves, especially at the antero-ventral region (as in fig. 9*a* of pl. vii, "Monograph of the Ceratiocaridæ," 1888); also by small raised spots more or less isolated. Among these, however, there is generally one small pustule that seems to be analogous to the little ocular tubercle in *Emmelezoe* ("Monograph Ceratiocaridæ," Pal. Soc. 1888, pp. 69–71, pl. vii, fig. 9, and pl. viii, figs. 1–3). In one specimen (not figured) it is accompanied by a small scutcheon with a wrinkled pattern.

The valves are chitinous, amber-coloured, somewhat iridescent, delicately thin, and brittle. The form is obliquely sub-oblong; somewhat boat-shaped; nearly straight on the back; elliptically and obliquely curved below; broadest (highest) in the anterior moiety, the antero-ventral curve being well developed. The front end has its apex on the median line of the valve; and is more frequently preserved than the posterior, which tapers, and was truncate with an ogee curve.

One specimen measures	13 × 6 mm.
Another specimen measures.....	11 × 4 mm.
Another specimen (Fig. 2) measures	10 × 4 mm.

This form is nearest to *Emmelezoe Maccoyiana* (Monograph, pl. viii, fig. 2); it has a greater antero-ventral curve than *E. elliptica* (fig. 1); and it is relatively longer and less boldly curved on the ventral border than *E. crassistriata* (fig. 3) and *E. tenuistriata* (pl. vii, fig. 9). Moreover, it shows none of the striate ornament seen in all these. The absence of this sculpture and the feebleness of the ocular tubercle weaken its apparent alliance with *Emmelezoe*; but we cannot associate it with *Ceratiocaris solenoides*, *C. inornata*, and their allies (Monograph, pp. 48–54, pls. viii and x).

In the Geological Magazine, Decade IV, Vol. II, p. 170 (April 1895), Dr. G. J. Hinde, in an abstract of a memoir by Prof. G. Lindström, communicated to the Royal Swedish Academy of Sciences in December, 1894, gives an account of the finding of these and other interesting Upper Silurian fossils, including fish-remains (*Cyathaspis*).

3. Lingulocaris lingulæcomes, Salter, 1866. Pl. XV, Figs. 3*a*, 3*b*.

In the "Monograph of the British Palæozoic Phyllocarida" (Palæont. Soc.), 1892, this species is treated of with its Synonymy, at p. 81.

The Rev. G. C. H. Pollen, S.J., F.G.S., of St. Beuno College, St. Asaph, has kindly communicated a specimen of what seems to be this species from Capel Arthog, between Barmouth Junction and Dolgelly, North Wales.

It is the hollow cast of the outside of a right valve, lying on a bed-plane of a bluish slaty rock, with ferruginous stains, belonging to the Lingula-flags (probably the Ffestiniog or Middle Division).

In shape it is obliquely subovate (28 mm. long; 13 mm. high); broad (high) in front, narrower and rounded behind. The anterior extremity of the valve is boldly rounded in advance of the umbo, but has a slight antero-dorsal slope. The hinge-line is straight (17 mm.) from the umbo to the postero-dorsal curve. The umbo is about a fourth of the length of the valve from the front end. Ventral edge elliptically curved; deepest just in front of the middle of the valve. The surface is marked with numerous thin striæ, parallel with the ventral margin, and concentric with the umbo.

This specimen most nearly agrees, as to shape, with Salter's fig. 2, pl. x, "Memoirs Geol. Survey," vol. iii (1866), pp. 253 and 294; and second edition (1881), p. 485, being more ovate than his fig. 1. Its ornament agrees with that of the latter. The variation in outline may possibly be due to sexual difference.

4. Cypricardinia (?), Hall, 1859. Plate XV, Figs. 4*a*, 4*b*.

This fragment of a molluscan valve, from Girvan, when looked at with its broken end downwards, has somewhat of the appearance of a fragmental upper moiety of a *Pinnocaris*, hence it has been figured tentatively in this plate.

Fig. 4*a* shows the outside of the posterior moiety of the right valve of probably a *Cypricardinia*, such as *C. sublamellosa* and *C. concentrica*, Hall, "Palæontology of New York," vol. iii, 1859, pp. 267, 268, pl. L, figs. 1 and 2. It measures 9 × 4 mm. Fig. 4*b* gives an enlarged view of a portion of its ornament.

The specimen is in Mrs. Gray's Collection, in Edinburgh, and was collected by her from the Lower Silurian rocks of Balclatchie, Girvan, Ayrshire.

5. Pinnocaris Lapworthi, R. Etheridge, jun., 1878. Plate XV, Figs. 5–10.

For descriptions and synonymy see "Monograph Silurian Fossils of Girvan," vol. i, 1880, p. 210, pl. xiv, figs. 17–20; and "Monograph British Palæozoic Phyllocarida," 1892, pp. 118, 119, pl. xv, fig. 24.

The only known representative of the peculiar Crustacean genus *Pinnocaris* occurs usually as black, shining, chitinous, flattened carapace-valves (sometimes decomposed); elongate and triangularly-obovate in outline; broadly rounded at one end (anterior); with an umbo; striæ parallel to the ventral margin and concentric with the umbo; and a long, narrow, transversely wrinkled posterior extremity.

In some instances the valves are subconvex; and often are evidently in pairs, containing matrix representing animal matter. In no instance have the two valves presented themselves as lying open or expanded side by side.

The umbo is situated on the straight margin, generally at about a fourth of the length of the valve from the anterior extremity; but in small specimens relatively at a less distance. It appears typically as a small pinched-up fold, hollow within; but it is much modified by pressure in different individuals; remaining sometimes as a

triangular ridge between two furrows; or as two small ridges bounding a triangular pit; or otherwise modified.

The straight edge of the long (posterior) portion of the valve has a corded appearance, from a little below the umbo to the extremity. This special margin begins very thin, and widens downwards, the little cross-striæ or wrinkles becoming stronger as it widens; the last eight or ten are much larger and thicker. In some cases (as in Fig. 9, more especially) it is double. Possibly this corded margin has reference to a peculiar dorsal longitudinal plate intermediate to the two valves. This may have been susceptible of being bent when the valves closed; or it may have split along its length. Such an intermediate dorsal plate is regarded by Hall and Clarke as having existed in *Mesothyra* ("Palæont. New York," vol. vii, 1888, p. 187, pl. xxxii, fig. 1); but we do not find it in the allied *Dithyrocaris*. The corded margin has a distant analogy to a lateral moiety of the intermediate and striated plate in *Pholadocaris*, H. Woodward (Geol. Mag., Dec. II, Vol. IX, 1882, p. 388, Pl. IX, Fig. 16). It more closely resembles the much stronger, corded, dorsal edges in *Dithyrocaris tricornis*, H. W. and R. Eth. (Geol. Mag., Vol. X, 1873, pp. 483–6, Pl. XVI, Fig. 3), which does not seem to possess an intermediate dorsal plate. *Pholadocaris* has been met with only in its expanded form; but *Dithyrocaris* has been found both in the expanded and closed state.

The two valves of *Pinnocaris*, if placed side by side, with the straight edge of one in contact with that of the other, would present an analogy to some of the flat open carapaces of *Pholadocaris* and *Aptychopsis*, with the difference that there would be little or no nuchal notch with the two valves of *Pinnocaris* thus arranged, and a very narrow open space below the umbo, not gaping at the end.

Judging from the two outlines of the counterparts of the closed carapace (Pl. XV, Figs. 8 and 9), we may say that when the valves were closed the dorsal edges would lie against each other (with or without a very narrow flanging ligament), whether they formed a straight or a slightly flexuous line, with or without a protruding umbo. Even anteriorly the edges would meet (with a slope), and would not necessarily require an intermediate plate. So a bivalve Mollusc, if laid open, would have angular notches fore and aft, but no intermediate plates.

As far as mere outline is concerned, *Pinnocaris* has a distant resemblance to a figure of *Beecherella subtumida* in E. O. Ulrich's memoir on that genus, "American Geologist," vol. viii, 1890, p. 200, pl. ii, fig. 6; but it is very distinct in other respects. The outline may be said to have a still more remote likeness to *Protozoëa Hilgendorfi*, Dames, "Zeitsch. d. Geol. Ges.," vol. xxxviii, 1886, p. 577, pl. xv, figs. 5–7.

Except one example from the Upper Silurian of Kendal, Westmoreland, all the specimens we have seen are from the Lower Silurian of Girvan, Ayrshire, from which locality Mrs. Gray, of Edinburgh, has made a large collection.

THE SIZES OF COMPLETE SPECIMENS.

No. in Mrs. Gray's Collection.	In millimètres. Length.	Width.	Figures in Pl. XV.	In Monograph Girvan Fossils, 1880, Pl. XIV.
2	34	13		
1	33½	12⅔	Fig. 5.	"Fig. 17."
28	32	9		
10	30	13		
6	30	12		"Fig. 18."
15	30	10	Fig. 10.	
8	30	8⅔	Fig. 8.	
7	28	10	Fig. 7.	
14	28	10		
9	28 ?	7⅔	Fig. 9.	(Counterpart of Fig. 8, but damaged in its upper moiety.)
11	27	11		
12	25	7		"Fig. 20."
3	24	7		
26	22	7		
13	22	5		
24	14	5	Fig. 6.	
29	14	5		

The Kendal specimen in the Monograph Brit. Foss. Phyllopoda, 1892, p. 118, pl. xv, fig. 24: Length, 25 ? mm.; width, 10 mm.

The apparent size of the specimens is considerably affected by the degree of pressure or amount of distortion they have received.

EXPLANATION OF PLATE XV.

1*a*, right valve; 1*b*, outline of end view.

FIG. 1. *Ceratiocaris reticosa*, sp. nov. From near Ludlow. Museum of Practical Geology, Jermyn Street.

FIG. 2. *Emmelezoe Lindstroemi*, sp. nov. 2*a*, left valve, natural size; 2*b*, the same, magnified 3 diameters; 2*c*, outline of edge view; 2*d*, outline of end view. From Lau, Gothland. Brit. Mus.

FIG. 3. *Lingulocaris lingulæcomes*, Salter. 3*a*, hollow cast of right valve, × 1½ diameters; 3*b*, outline of transverse section. Capel Arthog, North Wales. Collection of Rev. G. C. H. Pollen, F.G.S.

FIG. 4. *Cypricardinia*. 4*a*, imperfect right valve, twice nat. size; 4*b*, portion of the ornament, magnified 25 diameters. From Balclatchie, Girvan. Mrs. Gray's Collection, Edinburgh.

FIG. 5. *Pinnocaris Lapworthi*, R. Etheridge, jun. 5*a*, carapace, one and a half times nat. size. The upper part is convex, and exhibits the outside of the left valve, which is broken across at the umbo, showing a thin layer of brownish matrix between the valves. The inside of the right valve forms the lower part of the figure. The crushed spikes at the side are quite distinct, and must have belonged to some other organism, having no relation to *Pinnocaris*. They seem to consist of a once convex tapering style, now crushed along its middle, and a much smaller, obscure, thin, and simple spike or spine lying below the other and nearly parallel with it. 5*b*, approximate outline of the convexity of the upper (front) end. From Balclatchie, Girvan, Ayrshire. Mrs. Gray's Collection.

FIG. 6. *Pinnocaris Lapworthi*, R. Etheridge, jun. 6*a*, convex cast of the interior of a right valve, 3 times nat. size; 6*b*, outline of the edge view; 6*c*, a small portion of the linear ornament of the test preserved at the antero-ventral curve, enlarged 25 diameters. From Ardmillan Brae, Girvan. Mrs. Gray's Collection.

FIG. 7. *Pinnocaris Lapworthi*, R. Etheridge, jun. A flattened carapace: the upper part shows a portion of the outside of the right valve; the lower part is the slightly hollow inside of the left valve. From Balclatchie, Girvan. Mrs. Gray's Collection.

Fig. 8. *Pinnocaris Lapworthi*, R. Etheridge, jun. Concave mould of the outside of a left valve. From Balclatchie, Girvan. Mrs. Gray's Collection.

Fig. 9. *Pinnocaris Lapworthi*, R. Etheridge, jun. 9*a*, convex cast of the inside of left valve; counterpart of, and fitting into, Fig. 8; but imperfect at top and side of upper moiety. 9*b*, outline of edge view; 9*c*, outline of end view. From Balclatchie, Girvan. Mrs. Gray's Collection.

Fig. 10. *Pinnocaris Lapworthi*, R. Etheridge, jun. Probably a carapace; showing the right valve, of which the upper part retains the usual black shining test; and the lower part is the convex cast of the inside of the posterior moiety of the same. From Ardmillan Brae, Girvan. Mrs. Gray's Collection.

III.—Review of the Evidence for the Animal Nature of Eozoön Canadense.

By Sir William Dawson, C.M.G., LL.D., F.R.S., etc.

III. Structural and Biological.

In recent years I have been disposed to attach more importance than formerly to the general form and macroscopical characters of Eozoön. The earlier examples studied were, for the most part, imbedded in the limestone in such a manner as to give little definite information as to external form; and at a later date, when Sir William Logan employed one of his assistants, Mr. Lowe, to quarry large specimens at Grenville and Côte St. Pierre, the attempt was made to secure the most massive blocks possible, in order to provide large slabs for showing museum specimens. More recently, when collections have been made from the eroded and crumbling surfaces of the limestone in its wider exposures, it was found that specimens of moderate size had been weathered out, and could, either naturally or by treatment with acid, be entirely separated from the matrix. Such specimens sometimes showed, either on the surfaces or on the sides of cavities and tubes penetrating the mass, a confluence of the laminæ, constituting a porous cortex or limiting structure. Specimens of this kind were figured in 1888,[1] and I was enabled to add to the characters of the species that the original and proper form was "broadly turbinate with a depression or cavity above, and occasionally with oscula or pits penetrating the mass." The great flattened masses thus seemed to represent confluent or overgrown individuals, often contorted by the folding of the enclosing beds.

There are also in well-preserved specimens certain constant properties of the old calcite and serpentine lagoons. The former are continuous, and connected at intervals, so that if the siliceous filling of the chambers could be removed, *the calcareous portion* would form a continuous skeleton, while the serpentine filling the chambers, when the calcareous plates are dissolved out by an acid, forms a continuous cast of the animal matter filling the chambers. This cast of the sarcodous material, when thus separated, is very uniformly and beautifully mammillated on the surfaces of the laminæ, and this

[1] Geological Magazine, and Museum Memoir.

tuberculation gradually passes upward into smaller chambers, having amœboid outlines, and finally into rounded chamberlets. It is also a very constant point of structure that the lower laminæ of calcite are thicker than those above, and have the canal-systems larger and coarser. There is thus in the more perfect specimens a definite plan of macroscopical structure.

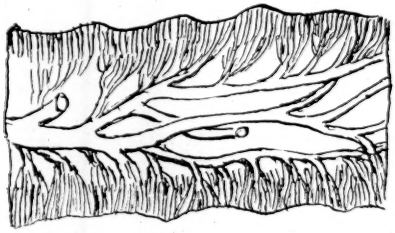


FIG. 6.—Diagram of typical mode of arrangement of canals and tubuli in a lamina of *Eozoön Canadense*. (Magnified.)

The normal mode of mineralization at Côte St. Pierre and Grenville is that the laminæ of the test remain as calcite, while the chambers and larger canals are filled with serpentine of a light green or olive colour, and the finer tubuli are injected with dolomite. It may also be observed that the serpentine in the larger cavities often shows a banded structure, as if it had been deposited in successive coats, and the canals are sometimes lined with a tubular film of serpentine, with a core or axis of dolomite, which also extends into the finer tubuli of the surfaces of the laminæ. This, on the theory of animal origin, is the most perfect state of preservation, and it equals anything I have seen in calcareous organisms of later periods. This state of perfection is, however, naturally of infrequent occurrence. The finer tubuli are rarely perfect or fully infiltrated. Even the coarser canals are not infrequently imperfect, while the laminæ themselves are sometimes crumpled, crushed, faulted, or penetrated with veins of chrysotile or of calcite. In some instances the calcareous laminæ are replaced by dolomite, in which case the canal-systems are always imperfect or obsolete. The laminæ of the test itself are also in some cases replaced by serpentine in a flocculent form. At the opposite extreme are specimens or portions of specimens in which the chambers are obliterated by pressure, or occupied only with calcite. In such cases the general structure is entirely lost to view, and scarcely appears in weathering. It can be detected only by microscopic examination of slices, in parts where the granular structure or the tubulation of the calcite layers has been preserved. All palæontologists who have studied silicified fossils in the older rocks are familiar with such appearances.

It has been alleged by Möbius and others that the canal-systems and tubes present no organic regularity. This difficulty, however, arises solely from imperfect specimens or inattention to the necessary results of slicing any system of ramifying canals. In Eozoön the canals form ramifying groups in the middle planes of

the laminæ, and proceed at first almost horizontally, dividing into smaller branches, which ultimately give off brushes of minute tubuli running nearly at right angles to the surfaces of the lamina, and forming the extremely fine tubulation which Dr. Carpenter regarded as the proper wall. In my earlier description I did not distinguish this from the canal-system, with which its tubuli are

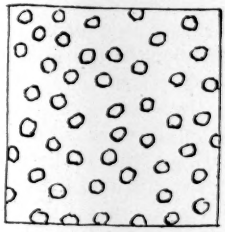


Fig. 7.—Cross section of minute tubuli, about 5 microms. in diameter. (Magnified.)

inwardly continuous; Dr. Carpenter, however, understood this arrangement, and has represented it in his figures[1] (see also Fig. 6). It is evident that in a structure like this a transverse or oblique section will show truncated portions of the larger tubes apparently intermixed with others much finer and not continuous with them,

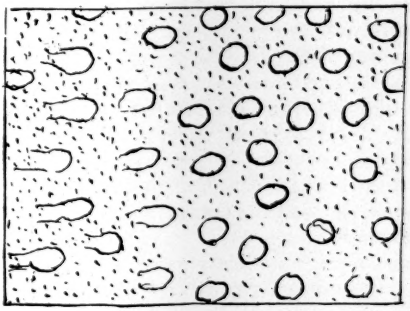


Fig. 8.—Cross section of similar tubuli, more highly magnified, and showing granular character of the test. (From camera tracings.)

except very rarely. Good specimens and many slices and decalcified portions are necessary to understand the arrangement. This consideration alone I think entirely invalidates the criticisms of Möbius, and renders his large and costly figures of little value, though his memoir is, as I have elsewhere shown, liable to other and fatal objections.[2]

It has been pretended that the veins of chrysotile, when parallel to the laminæ, cannot be distinguished from the minute tubuli terminating on the surfaces of the laminæ. I feel confident,

[1] Ann. and Mag. Nat. Hist., ser. 4, xiii, p. 456, figs. 3, 4.
[2] Museum Memoir, pp. 50 *et seq.*

however, that no microscopist who has seen both, under proper conditions of preservation and study, could confound them. The fibres of chrysotile are closely appressed parallel prisms, with the optical properties of serpentine. The best preserved specimens of the "proper wall" contain no serpentine, but are composed of calcite with extremely minute parallel cylinders of dolomite about five to ten microms. in diameter, and separated by spaces greater than their own diameter (see my comparative figure, "Dawn of Life," p. 106; also Figs. 5, 6). In the rare cases where the cylinders are filled with serpentine they are, of course, still more distinct and beautiful. At the same time I do not doubt that observers who have not seen the true tubulation may have been misled by chrysotile veins when these fringe the laminæ. Möbius, for instance, figures the true and false structure as if they were the same.

Protest should here be made against that mode of treating ancient fossils which regards the most obscure or defaced specimens as typical, and those better preserved as mere accidents of mineral structure. In Tertiary Nummulites injected with glauconite, it is rare to find the tubuli perfectly filled, except in tufts here and there, yet no one doubts that these patches represent a continuous structure.

I have remarked on previous occasions that the calcite constituting the laminæ of Eozoön often has a minutely granular appearance, different from that of the surrounding limestone. This is, I presume, the "dusty" appearance referred to by Dr. Bonney. Under a high power it resolves itself into extremely minute dots or flocculi, somewhat uniformly diffused. Whether these dots are particles of carbon, iron, apatite, or siliceous matter, or the remains of a porous structure, I do not know; but similar appearances occur in the calcareous fossils contained in altered limestones of later date. Wherever they occur in crystalline limestones supposed to be organic, the microscopist should examine these with care. I have sometimes by this appearance detected fragments of Eozoön which afterward revealed their canals.

I have not space here to notice late observations on Archæospherinæ and other objects supposed to be organic found in pre-Cambrian rocks in Canada and in Europe. They afford, however, to some extent, corroborative evidence in favour of Eozoön.

Supposing a probability to be established of the animal nature of Eozoön, we should naturally expect to detect links of connection between it and fossils known to us in the succeeding geological formations. We have, however, here to make allowance for the probability that an organism so very ancient may differ materially from any of its successors, and may probably be a synthetic or generalized type, or present embryonic characters. Analogy might also justify the supposition that it might be represented in later times by smaller as well as more specialized forms. In this connection also, the probable warmth and shallowness of the Laurentian ocean, and its abundance in calcium carbonate and in carbonaceous matter, probably organized, should be taken into account. It should also be noted that the formations next in ascending order are of

a character little likely to preserve organic marine forms of the "benthos" or ground-living group. We might thus expect a gap in our record between the fauna of the Grenville Series and that of the next fossiliferous formations.

Logan naturally compared his earlier specimens with the Stromatoporæ so abundant in the Ordovician and Silurian Limestones; and in this he was justified, for, whatever may be the ultimate judgment of naturalists as to these problematical fossils, and whether they are referred to Protozoa or to Hydrozoa, or, as seems more likely, are divided between the two. they resemble Eozoön in general structure and mode of accumulation of calcareous matter, and occupied a similar place in nature. My own conclusion, on discussing the microscopic structures of the specimens of Eozoön, was that they were probably those of Protozoa allied to those Foraminifera with thick supplemental skeleton[1] which had been described by Dr. Carpenter. At the same time, I suspected that those Stromatoporoids, like Cœnostroma, which possess thick laminæ penetrated by ramifying tubes, might be allied to the Laurentian fossil. Dr. Carpenter regarded the structures as combining in some respects those of Rotaline and Nummuline Foraminifera, and ably, and as I think conclusively, defended this view when attacked.[2] The Rotaline type of Foraminifera has since that time been traced by Cayeux and Matthew far down into the pre-Cambrian rocks. The Nummuline type is not known so early. As to the canal-bearing Stromatoporoids, none of them show the fine tubulation, though some have radiating and branching canals. Recent students of the Stromatopora seem disposed to refer them to Hydrozoa,[3] a conclusion probable in the case of some of the forms (especially those spinous ones incrusting shells), but doubtful in the case of others, and more particularly the oldest of all, belonging to the genus Cryptozoön of Hall, and Archæozoön of Matthew,[4] the structure of which seems, so far as known, to consist of very thin primary laminæ with a supplemental tubulated skeleton resembling that of the genus *Loftusia*, and which must, I think, be regarded as foraminiferal. In any case, whether these primitive forms are Protozoa or rudimentary Hydroids, they reach back in time nearly as far as Eozoön, and are equally massive and abundant, and may be regarded as analogous to it in magnitude, habitat, mode of growth, and function in nature.

These later discoveries are gradually widening the horizon of palæontologists in the direction of the dawn of life, and the studies of those who trace backward the history of the Invertebrates of the Palæozoic seas are demanding more and more the discovery of earlier forms than those yet known to complete the chain of life.[5] The field is a difficult one to cultivate, and demands both labour and patience, but it holds forth the prospect of great discoveries, and it has already become the duty and interest of palæontologists to

[1] Calcarina, etc.
[2] Ann. and Mag. Nat. Hist., *loc. cit.*
[3] Nicholson, Monographs Palæontographical Society.
[4] Bulletin Nat. Hist. Survey of New Brunswick, 1894–5.
[5] See Dr. Woodward's Address as President of the Geological Society, 1895.

extend their inquiries as far back as the Laurentian in the search for Eozoic life.

In this respect the study and discussion of Eozoön have not been without use, in directing attention to the possibility of finding organic remains in the older crystalline rocks, to the danger of confounding them in their peculiar condition with merely mineral structures, to the state of preservation of organic remains in the older formations, and to the origin and significance of the large deposits of limestone, dolomite, hydrous silicates, iron ore, graphite, and apatite, laid up in certain horizons of the Eozoic rocks. Questions of this kind have been greatly advanced toward their satisfactory solution since the discovery of Eozoön in 1858, and in some degree at least in consequence of the interest excited by that discovery. It is hoped that the present notes may tend in the same direction, and that, whether or not they succeed in removing any existing scepticism in respect to Eozoön, they may help to stimulate and guide the search for those beginnings of life, which there are now the best reasons for believing are to be found far below the base of the Cambrian.

[Additional facts and illustrations, and references to previous papers on the subject, will be found in "Specimens of Eozoön Canadense," pp. 106, published by the Peter Redpath Museum (Notes on Specimens, Sept. 1888), which may be obtained on application to the Museum, or through W. Foster Brown, Bookseller, Montreal. See also, for a popular summary, Chapters v and vi of "Some Salient Points in the Science of the Earth," London, 1893.]

[For Parts I and II of this article see Geol. Mag. 1895, Dec. IV, Vol. II, No. X, October, p. 443, and No. XI, November, p. 502.]

Erratum.—November Number, p. 503, line 30, for *Aruprion* read *Arnprior*.

IV.—Zonal Divisions of the Carboniferous System.

By E. J. Garwood, M.A., F.G.S., and J. E. Marr, M.A., F.R.S.

ONE of us remarked last year in an article in *Science Progress* that "we may expect to find our Carboniferous deposits divisible into zones in a manner comparable with that which holds good among other . . . strata." The same writer called attention to the fact that similar views had been expressed by Waagen (Salt Range Fossils, "Memoirs of the Geological Survey of India, 1891"), who considered that the Carboniferous fossils had not received the same attention as those of other rocks.

In Russia, three important divisions of the Carboniferous have been made out: the stage of *Productus giganteus* and *Spirifera Kleini*, referred to the Lower Carboniferous; and the Moscovian stage, with *Spirifera Mosquensis*, and the Gshellian stage, with *Chonetes Uralica*, to the Upper Carboniferous. The marine type of Upper Carboniferous deposits has now been found widely distributed over Europe, Asia, Africa, and America, though represented by few truly marine beds in Britain; but the Lower Carboniferous strata are admirably represented in our country, and it is the object of this paper to induce local observers to pay greater attention to these beds than they have

hitherto done, and also to study such marine beds of the Upper Carboniferous (Millstone Grit and Coal-measures) as are developed in this country.

In 1886, De Koninck and Lohest showed that the Carboniferous Limestone of the north-east of England was divisible into three groups: the lowest, containing a number of corals and certain fish, including *Lophodus lævissimus*, L. Ag., and *Copodus cornutus*, L. Ag.; the middle, with abundance of *Chonetes papilionacea*, Phill.; and the upper, with *Productus giganteus*. Since that time one of us (E. J. G.) has paid considerable attention to the Lower Carboniferous strata of the northern half of the Pennine Chain, and whilst corroborating the views of the Belgian writers as to the relative position of the two Brachiopods above mentioned, has also detected the occurrence of other fossils in a definite order in that district. So far, the following succession has been made out (in descending order):—

Beds with *Productus* cf. *Edelburgensis*	Yoredale Series.
,, *P. latissimus*	
,, *P. giganteus*	Mountain Limestone Series.
,, *Chonetes papilionacea* and *Chætetes septosus*	
,, *Spirifera octoplicata*	

The beds containing *Productus latissimus* have now been traced, occupying the same relative position from the Settle district of Yorkshire into Northumberland.

Starting in the Ingleborough district, a well-marked horizon is found, characterized by very fine specimens of *Productus latissimus*, occurring at the base of the "Yoredale Series" in thin argillaceous limestone (being the limestone next above the top of the "Lower Scar Limestone" in that district = second limestone of Sedgwick: "Description of a Series of longitudinal and transverse sections through a portion of the Carboniferous Chain between Penigent and Kirkby Stephen,"—Trans. Geol. Soc. 1831, vol. iv, pl. vi, fig. 1).

Proceeding northward to Wensleydale, the same fossil is found in a limestone apparently higher in the series, the Hardraw Scar Limestone (see Mem. Geol. Survey Explanation of Q.S. 97 N.W., p. 200). In the Cross Fell escarpment *P. latissimus* occurs in the High Cup Valley in the second limestone above the Lower Scar Limestone (Melmerby Scar Limestone), the latter being characterized at the top by the presence of *Productus giganteus*. On the other (eastern) side of the Pennine watershed, *P. latissimus* is found everywhere in the upper parts of the valleys of the Tyne, Wear, and Tees where the "great" or "main" limestone, in which it is here embedded, occurs. The limestone with *P. latissimus* is, therefore, separated by several intermediate limestones from the Melmerby Scar Limestone.

Still further to the north and east, a thin limestone is found to be crowded with *P. latissimus* on the north-east coast immediately south of Howick Burn, the bed in which it occurs being separated from the Great Limestone (at a lower horizon) by some thickness of mechanically formed sediments.[1]

[1] For further details concerning this section, see Garwood, in "History of Northumberland," by E. Bateson, vol. ii, p. 330.

The reason for the existence of *P. latissimus* at what is apparently a constantly higher horizon as compared with the Lower Scar Limestone, as we proceed northward, we hope to discuss elsewhere; at present we wish to call attention to the fact that, whatever the lithological characters of the strata, the beds with *P. latissimus* occur definitely above those with *P. giganteus*.

The writers hope to obtain further information concerning the minor subdivisions of the Carboniferous rocks of the Northern Pennine region, and in the meantime would urge observers to study the distribution of the Carboniferous fossils in other regions. The Southern Pennine Chain, the neighbourhood of the Bristol Coal-field, and the Carboniferous rocks of North and South Wales would probably repay the labour of a minute study; and local collectors are particularly requested to note the exact horizon of each fossil which they obtain, a task by no means difficult, with the admirable detailed maps of the Geological Survey to serve as a guide. The writers' observations coincide with those of others who have attempted to differentiate minor divisions of the Carboniferous strata, indicating that the Brachiopods are most likely to repay one in carrying out such work; but the remarkable results which have followed from a careful study of the Ammonites would suggest the desirability of careful collection and examination of the *Goniatites*, which are pretty abundantly found in most districts. At the same time, other groups of fossils should not be neglected; corals, especially, will probably yield valuable information in the hands of specialists.

It is daily becoming more apparent that the Carboniferous period was not, as some have supposed, a comparatively brief period, throughout which sediment accumulated with exceptional rapidity. The remarkable discovery by Dr. Hinde and Mr. Howard Fox of thick deposits of Radiolarian cherts in Devon, Cornwall, and Somerset, is of particular interest from this point of view. It can hardly be doubted, therefore, that fossil zones, such as have been defined in strata both older and newer, can also be detected in the beds of Carboniferous age; and if so, it is fully time that the necessary work should be done in strata of such importance. That it has not already been achieved is a probable indication that the task will be a more difficult one than that of separating the Lower Palæozoic or Mesozoic rocks into zones, and may probably be too much for one or two workers. We therefore suggested at the recent meeting of the British Association that a committee might be formed to inquire into the possibility of dividing the Carboniferous strata of Britain into fossil zones; that it should be the duty of the committee to call the attention of local observers to the desirability of collecting Carboniferous fossils, making accurate notes as to the horizon of each, and paying special attention to the Corals, Trilobites, Brachiopods, and Cephalopods; and that the services of eminent specialists who have studied these groups of fossils should, if possible, be retained by the committee, to study the specimens submitted by the local observers.

V.—The Destruction of the Chalk.

By Grenville A. J. Cole, M.R.I.A., F.G.S.,
Professor of Geology in the Royal College of Science for Ireland.

MR. A. C. G. CAMERON, of the Geological Survey of England and Wales, published in 1893 [1] an account of a boulder of chalk so large that the village of Catworth has been built upon it, while springs arise between it and the clays which underlie the mass. Sir A. Geikie [2] now reports the interesting discovery that "a cake or floor of chalk, lying at the base of the Boulder-clay, may be traced over an area of more than twenty square miles in the west and north of Huntingdonshire and in northern Bedfordshire. It crops out more or less continuously along the brow of the hills under the Boulder-clay and rests on the Oxford Clay. It probably consists of many large sheets of chalk which, at the beginning of the deposit of the Boulder-clay, were transported from the chalk hills lying to the east and north-east."

Here we are met by the old question which has so often been discussed in presence of the chalk-masses of Cromer. Have we necessarily to do with glacial action on a large scale, or with processes of disintegration which have broken up the Chalk almost *in situ*? This massive limestone, traversed by continuous vertical joints, is a ready prey, in our cliffs and quarries, to undermining influences, and to the flaking action of frost. The great rock-falls of Dover or of the Dorset coast would furnish very respectable boulders to any "drift" now forming in the Channel. The famous landslip of Axmouth affected the Chalk to a depth of more than 100 feet, and was accompanied by the contortion and upthrust both of the older and more recent strata along the shore. Hence blocks of very various age became mingled together, "invested with sea-weed and corallines, and scattered over with shells and star-fish," [3] representing the existing fauna. Mr. Mellard Reade [4] has elaborated a combined terrestrial and drift-ice origin for the Cromer boulders; and, in the discussion on his most suggestive paper, Prof. Hughes compared the phenomena to those of the landslips near Lyme Regis, in the Isle of Sheppey, and along the river Clwyd.

Chalk resting upon clay along a shore-line is liable to a rapidity of destruction, taking place on an extensive scale, which is nowadays scarcely realized by those who dwell at some distance from the coast. Since catastrophic sea-waves and recurrent deluges have been all but banished from our speculations, it has been the custom to ascribe anything that shows evidence of violence to the glaciers of the Ice Age; and these glaciers have grown in dimensions in proportion to the work ascribed to them. But the storms of the

[1] "Notes on a transported mass of Chalk in the Boulder-clay, at Catworth, in Huntingdonshire": Glacialists' Magazine, vol. i, p. 96. Also Fortieth Report of Department of Science and Art (1893), p. 249.

[2] "Annual Report of the Geological Survey and Museum of Practical Geology for 1894": Forty-second Report of Department of Science and Art, p. 274.

[3] W. D. Conybeare, letter quoted by Lyell, "Principles of Geology," eighth edition, p. 310.

[4] "On the Chalk-masses or Boulders included in the Contorted Drift of Cromer": Quart. Journ. Geol. Soc., vol. xxxviii (1882), p. 222.

winter of 1894–5, and their effects upon the coast of County Antrim, may teach us an important lesson in the destruction of the Chalk by more ordinary natural causes.

The constant landslips at Garron Point and near Glenarm have given rise to a number of masses of chalk, overriding and embedded in the deposits of the present sea, so that the coast, were it upheaved, could with difficulty be differentiated from that of Cromer. The modern sands of the Channel are here mingled with the débris of glacial "drifts," which contain the fragments of shells that marked a colder period. A singular confusion of materials could thus be dredged up close to the land, and blocks brought by floating ice from a distance, such as the eurite of Ailsa Craig, are familiar objects upon the shore. These latter may represent, on the scale of our Antrim illustrations, the Norwegian rocks in the drift of Cromer.

The great storms of the last fortnight of December, 1894, added a large portion of the coast-road to the modern "drift" deposits of the Irish Channel; and they have also provided us, on the north side of County Antrim, with an effective model of the newly discovered floor of Huntingdonshire.

I am indebted to Mr. R. Welch, of Belfast, for a description of the scene in Whitepark Bay, between Carrick-a-rede and the Giants' Causeway. The Chalk and the Greensand here rest characteristically upon the Lower Lias, the clays of the latter series providing the former with an easy gliding-plane. Doubtless the shore for some distance seaward is formed of detached masses of the Cretaceous strata; but the storm-waves have now swept clear from sand an area of, on an average, 1000 feet by 100 feet, its width at the centre being about 250 feet. Mr. Welch has, as usual, made a very successful photographic record of the rocks exposed (No. 5119 in his geological series). The whole area is seen to be covered with blocks of chalk, which are often 10 feet long; they are almost in contact, and are bounded above and below by their planes of stratification, like flakes that have been moved only a short distance from their original position. In the cleft-like intervals between them, the dark surface of the Lias clays is everywhere visible. It is as if a massive bed of chalk had been broken up almost *in situ*; and we probably have here a picture in miniature of many miles of the submarine coast of County Antrim. The spaces between the blocks at Whitepark Bay will, in time, become filled up with modern beach-material; and we only want floating ice in the Channel to embed them in a glacial sand or in a Boulder-clay. Their environment will be a shifting material, liable to compression and even to contortion, as new masses ooze out slowly from the land. Mr. Welch's photograph thus seems to reveal to us what we may call a land-slide-phase, rather than a catastrophic landslip-episode, in the destruction of the Chalk. I venture to think that it represents an early phase in the history of the huge chalk-flakes and associated drifts that are being studied in England by Mr. A. C. G. Cameron. The picture is a striking record of the way in which massive chalk may go to pieces, and may be moved outwards on a gentle slope, while yet preserving its stratified aspect and a certain air of continuity.

VI.—Observations on East Anglian Boulder-clay.

By the Rev. E. Hill, F.G.S.[1]

I DESCRIBE some facts which have attracted my attention in my neighbourhood as bearing on the question of the East Anglian Boulder-clays, and I note the directions in which these facts would seem to lead our ideas. For the most part I limit myself to my own observations.

The soil of my neighbourhood is extremely heavy. Boulder-clay is the subsoil, and is often turned up by the plough. The great lumps and clods are dried by the sun into masses almost as hard as brick. But these iron clods, penetrated by the frosts of the severe winters we have lately had, become such that, after the frost has passed away, at the tap of a stick they crumble into a fine powder and almost into dust. If such be the effect of present winters, what may not have been within the power of winters in the great Ice Age. It should be noted also that the matrix of the East Anglian Boulder-clay seems chiefly Kimmeridge clay, while that of the Midlands is, I believe, chiefly Keuper and Lias. These are clays which frost would pulverize, and which occur in the respective regions. There is, then, no need to call in a glacier grinding-mill to make a matrix for the Boulder-clay. These observations seem to point to the land-ice theory being unnecessary.

In the matrix of clay, besides flints, there lie pieces of chalk of every size, from boulders measured by yards down to the pea and the pin's head. I find it difficult to understand how a glacier could grind chalk to anything other than powder. But frost makes the face of a clunch wall or chalk quarry scale off, and showers down pieces of every size. The number of these pieces in the clay is great. I have tried to count the number in a definite area. Counting only pieces of pea size and upwards, I have twice found as many as ninety to the square foot. How come these to be so intimately mingled with the clay-matrix.

Again, how are the clay and chalk brought together at all? The Kimmeridge clay all lies far to the west of Suffolk; I know of none nearer than Ely. On the other hand, chalk occurs as a constituent of Boulder-clays in the Midlands far to the west of all Cretaceous beds. Chalk, then, has been carried westwards, and clay in the opposite direction. What was the agent which could carry east and west at once? Certainly not those glaciers whose course can be mapped by their contents. These observations seem to indicate that the land-ice theory is impossible.

In digging wells many blocks of chalk and limestone brought up are found to be striated or scratched. One such (which was shown), from a well at Felsham, is scratched on one side only; the other side is a mass of fossils, unscratched. It may be a split portion of a larger block, or it may have had one side protected by ice. But in any case clearly it was scratched first and placed in the clay

[1] A paper read at the Ipswich Meeting of the British Association.

afterwards. If the stone and the clay were deposited together, and deposited by water, the appearance is intelligible. The natural explanation is that the Boulder-clay was deposited in water, and that ice, floating over this water, carried stones and dropped them.

The clay is found in West Suffolk up to heights of 340 feet; but none of the neighbouring outcrops of chalk reach 300 feet. I have attempted to trace the contour-line of 300 feet from the Tees to the Thames. The tracing shows that chalky Boulder-clay in East Anglia attains a higher level than any ground northwards up to the Lincolnshire Wolds. Even there, the elevated area of chalk is smaller than the equally elevated area of East Anglian clay. Besides, Mr. Deeley tells us that chalk-drift is found in Leicestershire up to 800 feet, which is far higher than any Northern chalk. It seems, therefore, natural to suppose that much chalk country was then relatively higher than now; accordingly that a tilt of the surface has taken place since Glacial times.[1] This is similar to a conclusion which Prof. Prestwich arrived at, on the independent evidence of his Westleton beds.

Another observation of mine may have a significance. In some brickyards a coarse clay is ground up with water and allowed to settle in shallow pits. A similar material is produced in Cambridgeshire when the mud, washed off from coprolites, has been run into the 'slurries.' When I have seen these pits cut into, their material in its texture has sometimes strongly recalled to me some of the finer varieties of Boulder-clay—for instance, the chocolate-coloured clay of Holderness. This likeness suggests that the deposition of Boulder-clay was a process which went on rapidly. If so, the formation may have taken place in less time than we are accustomed to suppose.

The above observations, then, taken together, suggest the picture of a broad sheet of water surrounded by slopes of clay and scarps of chalk. These are to be broken and pulverized by winter-frosts, and washed down in muddy torrents by spring or summer rains, while stones embedded in ice are also carried down, scratched in the transit, and floated far before they are dropped. But the surface of these waters cannot be still, nor even flowing in a uniform direction. There must be tides, eddies, or varying winds, since something seems required to drift the ice-rafts across the movement of the muddy waters, so as to produce the mixture of materials which we find.

I have confined myself to my own area and my own observations; also I have made no attempt to answer the difficulties which may be raised. There are, however, two obvious objections on which something may be said. It is urged that if the Boulder-clay be of aqueous origin, it ought to contain fossils and be stratified. If my

[1] This argument of course assumes the conclusions previously arrived at. Those who maintain glacier-transport should bear in mind that, unless levels have changed, the ice must have been at a yet higher level above the spot whence it brought the chalk. If this came, for instance, from Speeton, Flamborough Head must then have been buried beneath 500 feet of ice.

suggestion that it was formed rapidly have any truth, fossils need not be expected. Thick muddy waters would probably be quite unfitted for life. I do not think there are fish in the muddy Swiss glacial streams.[1] And the artificial clays I have described sometimes show little or no stratification on a small scale. On a large scale the Boulder-clay *is* stratified. I have seldom gone far without finding traces of this. Often, indeed, it is as clearly stratified as any other clay.

There are doubtless many other difficulties, some of which may be fatal. I offer this paper as an independent contribution to a most controverted, and therefore most attractive, question.

VII.—British Geology in relation to Earth-Folding and Faulting.[2]

By T. Mellard Reade, C.E., F.G.S., F.R.I.B.A.

THE history of every science may be compared to the ascent of lofty and diversified mountains, in which level benches and plateaux alternate with steep and rugged slopes. The first explorers, beginning at the base, toil upwards, hardly knowing which course to take, and having little idea of the country that lies before and above them. But they toil on, gathering information as they go, until, reaching a level resting-place, they can look back and form a more accurate conception of the country they have traversed. Still, they can see but a little way upwards, much less perceive the summit, but ascend they must, gaining an ever-widening view and grander and more just conceptions of the wide world below.

It is thus that the study of geology has progressed. By the combined operation of an army of explorers a vantage-ground has been obtained from which we are enabled to review our position and determine upon the next point of attack.

The history and succession of the rocks have been traced, their position in time and in part, their location in space—but the latter knowledge can never be complete until the whole world has been surveyed, both above and below the waters; now a seemingly impossible task: yet who shall speak for the future?

By the aid of numerous geologists, both great and humble, of all climes and countries, manfully working towards a common end, the order of succession has been outlined, and a fair but very crude knowledge of the earth's history reached. So far as palæontology and stratigraphy can speak, they tell us a good deal, but we cannot realize the meaning of it all without the aid of correct physical conceptions to reveal the processes of the wonderful earth-history which lies buried under our feet.

It is with this object that I ask your indulgence this evening in mentally travelling with me over the British Isles to see what help we can get from known British geology.

[1] In the discussion on this paper it was stated that the Dora Baltea, though thick with glacier mud, contains excellent fish.

[2] Presidential Address to the Liverpool Geological Society, 1895.

Facts of British Geology.

An examination of a good geological map of England and Wales, such as that known as Greenough's, published by the Geological Society, shows at once that the older rocks from the Cambrian to the Carboniferous constitute the bulk of the more essentially mountain areas.

Thus, North Wales is mainly Cambrian and Silurian; Cumberland and Westmoreland are largely composed of equivalent rocks, surrounded with a fringe of Carboniferous, which, more greatly developed in Northumberland, Durham, Yorkshire, and Derbyshire, forms the mountainous district of the Pennine Chain, the so-called backbone of Northern England. Leaving out of consideration for the moment the pre-Cambrian rocks of Anglesey and Shropshire, it is in the Cambrian and Silurian that the greatest deformations and foldings have taken place. Lying conformably upon the Upper Silurian in Herefordshire and Brecknockshire is the great thickness of Old Red Sandstone, more horizontally developed, but yet in the Beacons of Brecon and the Fans of Carmarthen rising as mountains from two to three thousand feet high. These are overlaid conformably by the South Wales Carboniferous rocks. In the North the Carboniferous Limestone lies unconformably upon the Silurian, the Old Red being practically absent. These Carboniferous rocks are in places considerably folded, the Pennine Chain itself being an anticlinal axis, while the Devonian and Carboniferous in Somerset and Devon are folded often at high inclinations in the Quantocks and the Mendips.

Surrounding these anticlinal areas, and in the depression between them, the Permian Limestone breccias and sandstones and the Triassic sandstones and marls lie unconformably upon the Carboniferous rocks, and much of this country is hilly, but cannot be correctly designated mountainous. The whole of the group of rocks, from the Cambrian to the Trias, occupy, roughly speaking, the western half of England, including Wales, but the eastern half of England is constituted of a succession of younger formations, from the Rhætic to the Pliocene. The Rhætic constitutes the passage from the Trias to the Lias, and, though nowhere developed on an extensive scale, is interesting as showing a conformable succession which is unbroken through the Oolites to the Upper Cretaceous. Between the Cretaceous and Eocene is an unconformable break representing a great time interval separating the Cretaceous and Tertiary, which is further confirmed by the complete change in the fauna and flora. The Eocene, Miocene, and Pliocene are conformable, and with them ends what is called the solid geology of the country, the succeeding deposits being Pleistocene, Glacial, and post-Glacial, consisting mostly of clay, sands and gravels, Boulder-clay and alluvium.

It is thus seen that the western half of England, together with Wales, possess the mountainous districts *par excellence*, while the eastern half is distinguished by gently undulating or horizontal strata, with sharp folds located in small areas, as in the Isle of Wight, at Purbeck, and the Yorkshire Chalk at Flamborough Head.

That the Lias had formerly extended over a considerable area of the western half is shown by the preservation of outliers in Shropshire, Staffordshire, and Cumberland, and *prima facie* it is probable that the overlying formations have also at one time in geological history been present. To a student of physical geology a glance at the geological map of England is sufficient to show that the outcrop of the Lias extending from the Severn to the Tees is an escarpment of denudation.

It must not be supposed for a moment that Britain represents the normal physiographic condition of the various formations all over the world, and that the mountain areas are always the oldest. Quite the contrary. In the Alps, Himalayas, and Rockies, in the mountains of the Caucasus and Central Turkestan, it is the younger formations that constitute the highest members of the mountain belts, and it is generally conceded that the bulk of the mountain-making in these chains has been geologically a late event.

Of course in great mountain chains we may have, and generally do have, the older rocks, even to the Archean gneisses and schists thrown up and exposed in their axial folds. This, however, as a rule, only shows that the earth movements to which they owe their birth and growth have been extreme and profound, involving the deep-lying sediments, and even their foundation rocks, in the general movement. We thus see that there is no intimate relationship between the *age* of the rocks of which mountain areas are composed and the existence of the mountains themselves.

The Mountain Areas of England and Wales as related to the thickness of the sedimentary and other deposits of which they are composed.

The Lower Cambrian Rocks of South Wales are estimated to have a thickness of from 3500 to 4000 feet, and are supposed to be over 8000 feet in North Wales. The Upper Cambrian, where well developed, attain a thickness of from 5000 to 6000 feet. The Ordovician, or Lower Silurian of the Survey, is estimated at from 12,000 to 25,000 feet; in Shropshire, according to Murchison, 18,000 feet; and between the Menai Straits and the Berwyns 19,000 feet. The Silurian, or Upper Silurian of Murchison and the Survey, may be 14,000 feet in the north-west of England, and from 3000 to 6000 feet in Wales. The total thickness of British Silurians, Lower and Upper, is stated by Murchison to be from 26,000 to 27,000 feet. Thus, from the base of the Cambrian to the top of the Silurian cannot be less than 35,000 feet.

We thus arrive at the grand aggregate thickness of from six to seven miles of rocks constituting the most mountainous parts of England and Wales. These rocks have suffered more intense deformation than any of the overlying formations, and have, as first lucidly explained by Ramsay, suffered enormous denudation since their folding and upheaval.[1]

[1] "Denudation of South Wales and the adjacent English Counties": Memoirs of the Geological Survey, vol. i.

The only break in the series of any moment occurs between the Ordovician and Silurian. There can be very little doubt that their areal extension was proportionately as great as their thickness. Between the Carboniferous and the Silurian there is a strong unconformity in the north of England and North Wales, but this is bridged over, as already explained, in Shropshire, Herefordshire, and South Wales, by the Old Red Sandstone, estimated at 10,000 feet. The Silurian shades upwards into the Old Red by well-defined passage beds, to be seen in many sections, while the Old Red graduates into the Carboniferous in no less perfect a manner.

The Carboniferous is an extensively developed formation in Britain. The base of Mountain Limestone varies in thickness from 1000 feet in Monmouthshire to 3000 feet in the Mendips in Somerset, while in Derbyshire it is 1600 feet, in the Vale of Eden 2000 feet, and in Llangollen 1200 feet thick. The Millstone Grit reaches a maximum of 5000 feet, the Coal-measures of South Wales 7000 to 8000 feet, and, according to Logan, reaches 10,000 to 12,000 feet in Monmouthshire, Glamorganshire, and Pembroke. In Lancashire the Coal-measures are 6600 feet, though the upper portions have been denuded.[1]

If we add these figures to the Cambrian and Silurian we arrive at a grand total of 55,000 feet, but it is not to be inferred that this occurs in any one place. Ramsay estimates the Silurians, Lower and Upper, the Old Red, and Coal-measures in South Wales at from 20,000 to 33,000 feet (Mem. of Geol. Survey, vol. i, p. 316).

It is of these enormously developed rocks that the typical mountain areas of England and Wales are composed. The question may well suggest itself to us whether there is not here a relation of cause and effect. We have seen that with the exception of the break between the Ordovician and Silurian there has been continuous deposit of sediment from the beginning of the Cambrian to the end of the Silurian, and still further, that in the Old Red Sandstone districts this sedimentation appears to have gone on almost uninterruptedly to the close of the Carboniferous. It is certainly a striking fact that a portion of the earth loaded with sediment to the vertical extent of some five to ten miles should be the very spot where the earth's crust has been elevated not less than four miles, according to Ramsay, and where even now the basal wrecks of these former gigantic elevations should reach 3000 feet above the sea-level. Consider for a moment what five miles of consolidated sediment means. It is equal to a load of 2000 tons per square foot on the normal crust of the earth.

This loading doubtless squeezed and shifted laterally some of the deeply lying and more mobile matter underlying the normal crust, until a balance of stability was attained. Then, by a process of expansion, the effect of a necessary rise of temperature of the old crust and overlying deposits, the conditions were reversed: the

[1] The authorities for these statements are principally Murchison and Ramsay, together with other authorities quoted by H. B. Woodward in the "Geology of England and Wales."

lengthening beds, unable to expand, laterally folded upon themselves, and the whole mass of sediment, by cubical expansion, increased in volume to the extent shown, by the rise of the mountain mass above the sea-level. But we are not to limit this action to the immediate mountain area, for the flanking area, probably largely constituted of more horizontal beds, now covered by newer deposits by successive lateral expansions, added to the folding and heaping up of the mountain masses.

Areas occupied by the Rocks newer than the Carboniferous.

If this relation between extensive and massive sedimentation and mountain-making stood alone it might justly be considered as merely accidental. I have, however, elsewhere shown that such relations may be traced in every known great mountain range; that formations here thinly developed and horizontal are in the Alps and Pyrenees, to go no further afield, extensive, thickly developed, and thrown into immense mountain masses.

In Britain the Permian and Trias, which lie unconformably upon the Carboniferous, reach a thickness of some 6000 feet, but the variation of thickness is very considerable from the overlapping of these formations on the mountain slopes. They are, however, as a rule, more affected by folding and faulting than the succeeding formations, and constitute some considerable hills and escarpments.

The Jurassic and Cretaceous occupy the largest part of the eastern half of England, and may be put down at perhaps 5000 feet, and the Tertiary at say 1500 feet; the total thickness of the British rocks from the Permian to the Tertiary inclusive, working out to about 12,500 feet. It is, however, very questionable whether such an aggregate thickness occurs in any one locality; while in the case of the older rocks, from the base of the Permian down to the base of the Cambrian they are developed in great thickness in direct superposition.

Characteristics of the Folding of the Eastern and Western Areas of England and Wales contrasted.

The rocks already described as occupying the eastern half and south of England are characterized by long low folds breaking into sharp anticlinals and synclinals at a few points only, such as in the Chalk at Flamborough Head and in the Tertiaries of the Isle of Wight, the eroded edges of these long folds forming the characteristic escarpments stretching across the country in a south-westerly and north-easterly direction. Sharply contrasted with these long undulations are the strata forming the mountain nuclei of Wales and Cumberland, where we find the rocks sharply bent and compressed, the remnants of the primitive folds forming by denudation the mountain scenery as now beheld by us. Intermediately we find areas of the Carboniferous and Old Red having a horizontal development, such as is to be seen in the Carboniferous of the neighbourhood of Whernside and Ingleborough, and can be well studied near to Dent, where the much contorted Silurians are in

juxtaposition to the less disturbed Carboniferous, the latter being let down by an enormous fault of unascertained throw. Again, in Herefordshire and South Wales we see a considerable extent of horizontal Old Red, which, as it approaches the Silurian mountain folds, becomes itself conformably inclined.

Not less interesting and instructive are the dome-like structures, such as the celebrated dissected Silurian dome of Woolhope, which rises in successive rings through the Old Red, which it carries on its flanks. May Hill is another similar structure, not so perfectly formed and also bisected by faulting against the Trias.

The physical constitution of Herefordshire and Brecknockshire is largely a horizontal plane of Old Red Sandstone, which, where it approaches the folded Silurian areas at the margins or round the enclosed domes, takes on the folds of the older rocks on which it lies.

Silurian and Old Red of the South-east of Scotland.

It will be instructive now to turn our attention to the rocks of a similar age to be seen dissected in the splendid line of cliffs from Berwick-on-Tweed to the far north of St. Abbs Head and Siccar Point. Here the Silurian (Lower Silurian) are intensely folded, and instead of the conformable succession from the Silurian, through the Old Red and Carboniferous which we have just seen obtains in Herefordshire and South Wales we see the Upper Old Red Sandstone conglomerate resting upon the edges of the Lower Silurian in the strongest unconformity. Well may the justly celebrated Hutton have exhibited this phenomenon, as seen at Siccar Point, as one of the best illustrations of the views he developed in the "Theory of the Earth."

So perfectly are the two formations cemented together that it is possible to get hand specimens of the unconformity. It would appear that while the sediments of South Wales were being laid down in quiet waters from the beginning of the Upper Silurian to the close of the Carboniferous, the succession of events was several times broken in Scotland, as shown, not only by the strong unconformity already spoken of between the Upper Old Red and the Lower Silurian, which I have myself seen, but by the unconformity Sir Archibald Geikie shows exists between the Lower Old Red and the Lower Silurian,[1] and even between the Upper and Lower Old Red[2]; and he further states "that the great earth movements which plicated the Highlands and Southern Uplands were probably simultaneous, and took place chiefly during the long series of ages represented by Upper Silurian deposits."[3] As the Upper Silurian in Lanarkshire passes gradually into the overlying Old Red Sandstone,[4] it is probable that the break between the Upper and Lower Silurian we have seen exists in England and Wales also extends to Scotland. The succession of events in the latter country are indeed more

[1] "The Geology of Eastern Berwickshire": Memoirs of Geological Survey, p. 20. "Scenery and Geology of Scotland," second edition, p. 122, also p. 138.
[2] *Ibid.* p. 329. [3] *Ibid.* p. 299. [4] *Ibid.* p. 327.

complex and difficult to trace than in South Britain, but it is sufficient for the present purpose simply to mention them as all pointing towards the immense range of geological time represented by the conformable Upper Silurian Old Red Sandstone and Carboniferous of South-west Britain.

Thickness and Extent of Rock Formations a measure of their plication.

The preceding sketch is little more than the barest outline of geological events recorded in the rocks of our own island, yet attentively studied the following facts stand out prominently:—The sedimentary rocks which were deposited in the greatest volume are those also that subsequently became most plicated. Though they were the earliest laid down they even now constitute the distinctly mountain masses of Britain, and possess actually the highest peaks and the highest average elevation. When it is considered that these mountains have been exposed to the destroying agencies of denudation for an enormous period of geological time, and still stand pre-eminent above those built out of younger formations, we may perhaps picture to ourselves in some slight degree the extent of the original mass. Not only are the Cambrian and Silurian formations here of enormous thickness, but they are of surprising and unknown extent, and they are found whenever denudation has proceeded far enough to bare them to the eye.

Again, the Carboniferous, taken together with the Devonian and Old Red Sandstone, occupying the second place in the mountain structure of the British Isles, consist of great masses of sediment, not indeed rivalling the Silurian in volume, but of great extent and thickness, though much denuded. Some portions are considerably folded, and most are greatly faulted, but as a whole do not show anything like the signs of lateral compression which are seen in the Cambrian and Silurian.

The Permian and Triassic rocks come next in time and, curiously enough, in importance as regards thickness, and the country they occupy, if not mountainous, possesses a more faulted structure than any of the following formations, and is of a more hilly character.

When we ascend to the Lias, Oolites, and Cretaceous, then the beds become more continuous, horizontal, and less faulted. Folds, and sharp ones, are to be met with, but these, as a rule, are local, the lateral pressure to which they were subjected having been less, and concentrated at fewer points. The same peculiarities apply to the Tertiary rocks, perhaps in a stronger degree.

Relation of Orographic Structures to the mass of the sediment composing them.

I trust that I have now said sufficient to show that there is in the British Isles an intimate connection between the depth, extent, and mass of the several great deposits marking the progress of geologically recorded events, and the structures into which they have been severally raised.

The mountain-building and the foldings and the faultings are,

roughly speaking, found to be proportionate to the original mass of the deposits out of which they have been fashioned by earth forces. If these facts stood alone they might be considered nothing more than curious coincidences. If, however, we cast our eyes abroad to the great continents we find that similar principles hold good, and that the mountain massives are related the world over to the thickness and volume of the deposits out of which they have been fashioned. Thus, the Alps, the mountains of the Caucasus, the Himalayas, are Tertiary structures; the Appalachians and Urals, Carboniferous; and these mountain chains are constructed of enormous thicknesses and volumes of sedimentary rocks.

Expansion and Contraction the cause of Folding and Faultings.

We may well ask ourselves why this relation between volume of sediment and greatness of disturbance should be so constant, and any theory of mountain genesis must necessarily explain these associated facts. The once favourite hypothesis which accounts for them by a shrinkage of the nucleus of the earth and the closing in of the non-shrinking crust upon it, and consequent folding by tangential pressure, fails to explain the constancy of the connection of great thicknesses of sedimentary rocks with the evolution of mountain ranges.

Neither does the principle of isostacy so insisted upon by American geologists explain the compression, folding, and building up of great masses of sediment into mountain ranges. On the principle of isostacy, it must be obvious to anyone possessing even a rudimentary acquaintance with mechanics that the sinking of the bed of the seas on which great deposits are accumulating, and to some extent a rise of surrounding land, may be explained, but not the lateral compression and elevation of the sediments themselves into mountain ranges.

Where, then, are we to look for the agency constantly associated with the deposit of great volumes of sediment which is capable of eventually upheaving them from below the sea-level, and by lateral compression and folding throwing them into mountain chains?

Again, when after the lapse of lengthened periods of geological time, denudation has cut away and removed into the sea large masses of elevated land, what agency is it that causes it to shrink and become traversed by great lines of faulting?

It appears to me now, even more vividly than it has done in the past, that the only agency with which we are acquainted constantly associated with sedimentation and denudation, and capable of these enormous dynamical effects, is change of temperature: that expansion by increase of heat is the cause of the folding, compression, and upheaval of rocks, while loss of heat and consequent shrinkage is the cause of the earth fractures known as normal faults. This principle I explained fully in 1886 in my "Origin of Mountain Ranges"; since then the theory has been subjected to much criticism, ranging from a questioning of fundamental principles down to a minor examination of small details.

The fundamental position has, I maintain, not been shaken, either by mathematical physics or geological facts. The more the theory is tested by the light of practical geology the more remarkable is the explanation it affords of the associated phenomena of sedimentation and mountain-building; denudation and faulting. Furthermore, no other theory yet brought forward attempts to offer an explanation of more than one set of these phenomena, namely, those of compression. Normal faulting cannot be accounted for by compression, yet the rival theory of tangential pressure on the crust through the shrinkage of the earth's nucleus provides for compression only. Contraction, by which I have shown that normal faults are produced, is not part of the machinery of any other theory than the one associated with my name.

I ask geologists to bring to the consideration of these great problems clearness of vision, for, usually, a single aspect only is examined, the rest being left in an impenetrable haze.

I trust I have now brought sufficient evidence before you to show that a broad examination of the formations of these islands, and their associated physical phenomena, throws a good deal of light on the problems of mountain-building, and that their remarkable relations are well worth more detailed examination than I have been able to give them in this address.

NOTICES OF MEMOIRS.

I.—Notes on some Tarns near Snowdon. By W. W. Watts, M.A., F.G.S.[1]

DURING a recent visit to North Wales, the writer has taken the opportunity of examining a few of the tarns in the immediate vicinity of Snowdon, including the two small lakes in Cwm Glas, Glaslyn, and Llyn Llydaw.

In the hollow of Cwm Glas there are two tiny tarns named Ffynnon Frech and Ffynnon Felen; both lakes drain over a barrier of rock, but in a rainy season the upper one appears to find a second outlet over the long, low col to the east, so that in this state it has the two outlets depicted on the six-inch map. The upper lake appears to be a portion of a bending valley dammed at both ends by scree and stream-débris, and thus compelled to find an escape over the rocky side. The lower lake is confined in a rock-basin, as rock occurs at its actual outlet and at every point where any former outlet might have been possible. The lake is, however, so shallow that its occurrence in a basin of rock is perhaps of little consequence.

The neighbouring hollow of Cwm Dyli, as is well known, contains three lakes, the highest being Glaslyn, the next Llyn Llydaw, and the lowest Llyn Teyrn. Glaslyn is bounded on all sides by live rock, except at and near its outlet. This exit is over moraine, which, however, is evidently not very deep, for rock makes its appearance just below, and in such a way as to almost compel belief

[1] Read before Section C of the British Association at Ipswich, September, 1895.

in a complete rock bar. Beside the present course of the effluent stream is a parallel strip of moraine running down towards Llyn Llydaw, but living rock soon appears in this in such a way as to show that if there be any old channel in this direction it must be exceedingly narrow and tortuous. If this lake be not contained in a true rock-basin it must be very shallow, or else must have found exit by a gorge quite as narrow as those found at the end of some of the Swiss glaciers.

Immense quantities of moraine material occur on the south-east side of Llyn Llydaw, but a careful examination of the map and the ground shows that only two possible outlets exist, that now used for this purpose, and a second which is occupied by bog resting on moraine, and gives rise to a small stream which is joined lower down by the outlet of Llyn Teyrn. The moraine is, however, only a thin skin on the surface of rock. The present outlet shows live rock 40 or 50 feet below the level of the lake, and the second possible exit at a rather less distance below the same level. If the moraine were stripped off, there is little doubt that this lake, like Glaslyn, would show a basin of rock which would hold water, unless it is very much shallower than is generally supposed to be the case.

II.—On Pitch Glaciers or Poissiers. By Prof. W. J. Sollas, D.Sc., F.R.S.[1]

PITCH and the ice of glaciers strikingly resemble each other in behaving as solids or liquids, according to their manner of treatment. On the sudden application of force they break like brittle material, but behave as fluids when subjected to gradual pull or pressure. Hence it is possible to employ pitch in the construction of working models of glaciers in order to obtain an insight into those internal movements of actual glaciers which are beyond the reach of direct observation. The study of glacial deposits has shown that many erratic boulders were transported, during the Glacial period, from lower to higher levels, and left stranded on the flanks of mountains some hundreds of feet above their source.

This standing difficulty in the way of physical theories of glacier-movement has been explained by the study of pitch models, which show that the lower layers of material on approaching an obstacle are carried up in an ascending current. The inference, which is confirmed by other kinds of observation, is that similar movements take place in actual glaciers. Further, a glacier sometimes overrides its terminal moraine without disturbing it; and in an experiment this was exemplified, for pitch flowed for several months over a ridge of loose material without carrying a particle of it away. A remark made by Professor Fitzgerald to the effect that viscosity seemed merely to retard, not to alter the nature of, the movement, in the cases described, led the author to experiment with less viscous material, such as Canada balsam and glycerine, with concordant

[1] Read before Section C of the British Association at Ipswich, September, 1895.

results. A trough containing balsam flowing upwards over an obstacle under its own head of pressure was shown by the lantern upon the screen.

A raised model of Ireland had been constructed, and the directions of ice-movement as determined by the Rev. Maxwell Close indicated upon it by arrows; on allowing water streaked with colouring matter to flow over it from two areas supposed to represent the great gathering grounds of snow of the Glacial period, the water had taken paths, as shown by coloured streaks, corresponding to those taken by the ice as shown by the arrows, a concordance in every way remarkable.

REVIEWS.

I.—The Geological Survey.

THE Report for the year 1894 of Sir Archibald Geikie, Director-General of the Geological Survey of the United Kingdom and Director of the Museum of Practical Geology, has reached us somewhat late in the present year. This is the more to be regretted, as the Report contains (in addition to the statistics relating to field-work, museum-work, and publications) a record of the chief scientific results obtained during the year.

Of the entirely new area in course of survey, that of the Isle of Man first calls for notice in the account of work done in England and Wales. There Mr. G. W. Lamplugh has discovered certain conglomerates in the Skiddaw Slate group, which he believes to have been produced by the breaking up of sandy slates and grits under intense shear strain. Unlike ordinary crush-breccias the included fragments often assume the characters of pebbles, rounded by attrition. The subject has been fully brought before the Geological Society, so that further reference here is not needful. No fossiliferous zones have as yet been determined in the Skiddaw Slates. With regard to glacial phenomena, the general march of the ice during the height of glaciation is noted to have been from some point west of north. It is stated that a bed of fine warp or silt in the glacial series of Kirk Michael may prove to be of some economic value: it has been used locally as a fuller's earth.

In areas that are being re-surveyed, those of the South Wales and other coal-fields are, without doubt, the most important. Portions of Glamorganshire, Brecknockshire, and Monmouthshire are being mapped by Messrs. J. R. Dakyns, A. Strahan, and W. Gibson, and in these (as in all other) areas where the Geological Survey is now engaged, the six-inch Ordnance Maps are utilized in the work. It is interesting to learn that, on the eastern border of the great coal-field, the several subdivisions of the Old Red Sandstone at present observed, appear to pass into each other, from the red marls and sandstones with cornstones up to the red sandstones, quartz grits, and conglomerates. The Carboniferous Limestone Series, as is well known, exhibits marked variations in the thickness of its

component strata, and it is noticed that in the middle of the main limestone there is, locally, a remarkable band of white oolite 40 feet thick. The chief lithological divisions in the Millstone Grit and in the Coal-measures are separately mapped, so that the structure of the ground may be clearly represented. This is of great practical value as regards the bands of clay-ironstone, the steam-coals, and other economic products.

Much new information has been obtained with regard to the extent of the boulder drift, and to the occurrence of Esker gravels in Monmouthshire and South Wales. Proof that the ice must have existed in considerable bulk has been obtained in the excavations of some new waterworks at Nant-y-bwch, where a hill of sandstone, upwards of 200 yards long, has been found to be a transported mass.

Some commencement has been made with the re-survey of the Leicestershire coal-field by Mr. Fox-Strangways, and of the North Staffordshire coal-field by Mr. De Rance.

It is satisfactory to learn that the results of these and other re-surveys will be published on the new series of the Ordnance one-inch maps, while MS. coloured copies of the six-inch maps are deposited in the Geological Survey Office for public reference.

In Devonshire and Cornwall, Mr. Ussher has been surveying the subdivisions of the Devonian formation and their associated igneous rocks; while in the southern counties Messrs. Whitaker, Reid, Bennett, Blake, Hawkins, and Jukes-Browne have been engaged in mapping the Drifts and re-surveying the Cretaceous and Tertiary rocks. The mapping of the Drifts in Yorkshire and in parts of the Midland counties has been continued by Messrs. Tiddeman and Cameron, who have likewise attended to needful revisions of the previous survey of the older and more "solid" formations.

In Scotland the Lewisian gneiss of the northern part of Raasay was mapped by Mr. Teall. It has been determined that the various crystalline rocks older than the Torridon Sandstone, and comprised under the general designation of Lewisian gneiss, may be divided into five distinct groups. The oldest and chief group is the "fundamental complex" of banded and foliated rocks, and this is considered by Mr. Teall to have decided affinities, both as regards chemical and mineralogical composition, with plutonic igneous products. A scheme devised by him for descriptive purposes, is now published in the Director-General's Report. Based primarily on mineralogical composition, and to a subordinate extent on structure, it shows the nature of the various rocks comprised within this "fundamental complex." In the other groups are included various dykes, gneissose granite, and pegmatite. The observations of Messrs. Peach and Horne prove that in certain areas the "Moine schists" have been produced by the alteration of the lowest Torridonian grits and shales.

Interesting results have been obtained by Mr. Hinxman in Strathspey, and by Mr. Barrow in Deeside, with regard to the relations of the great granitic masses.

The survey of the Island of Arran has been taken in hand by

Mr. Gunn, and he has found in the red sandstones, which extend along the eastern shore, and across the southern half of the island, a contemporaneous volcanic group. It is considered highly probable that these beds are of Permian age.

The older rocks and the Tertiary dykes of the south-east of Skye have been mapped by Mr. Clough, while Mr. H. B. Woodward has been engaged in the survey of the Jurassic rocks along the north-eastern borders of the island. With Mr. Symes in Cantyre, Mr. Wilkinson in Islay, Mr. Hill in the region between Loch Fyne and Loch Awe, Mr. Grant Wilson in Banff and Elgin, and Mr. Greenly (who has since retired) in Sutherland, the Geological Survey has made progress in various parts of Scotland.

In Ireland the work of revision has been carried out in different areas by Messrs. Egan, Kilroe, McHenry, and Sollas. The Croagh Patrick quartzite is now assigned to the Llandovery formation. In the tract of ground between Clifden and Oughterard there is a complex series of rocks which are considered to be equivalents of the Dalradian rocks of other regions. In the district of Pomeroy, in Tyrone, there is a belt of igneous rocks, lying between the Silurian and Old Red Sandstone rocks on the south and the crystalline schists on the north; and it has been found that they include lavas interleaved with cherts and jaspers exactly like those associated with the igneous rocks at the edge of the Highlands. It is surmised that the cherts, and certain overlying shales, etc., may prove to be of Arenig age.

II.—Les Variations périodiques des Glaciers. Discours préliminaire. Par F. A. Forel, President de la Commission Internationale des Glaciers. Archives des sciences physiques et naturelles. Genève. Vol. xxxiv, p. 209.

PROFESSOR FOREL commences by relating the formation of his committee, "sur l'initiative" of the writer of this notice. Each member, he tells us, is to organize—as seems best to him, and after the most useful fashion—historical, present, and future studies of glacier phenomena, and publish such in the periodicals of his own country; and a summary is to appear annually in the Archives des sciences, etc., of Geneva. He then proceeds to the consideration of what the phenomena to be studied consist in. Much of this ground has already been put forward by the writer, but there are points and extensions dwelt upon by Professor Forel which it may be acceptable to touch upon.

He rightly emphasizes the importance of concentrating our energies, more especially at first, upon the observation of actual advance, retreat, increase or diminution in bulk of glaciers, and to the simultaneity or otherwise of their variations in both hemispheres and all latitudes, as also to their relation to meteorological records.

As regards the study of névés, to the extent and quantity of which, of course, much of glacier variation is due, he thinks that, great as is the importance of such observations, we had better for

the present not complicate our work, but "occupons-nous seulement des glaciers proprement dits." The writer, though agreeing to a great extent with this, is unable to see how a definite line could profitably be drawn between food-supply and glaciers. However, M. Forel quite admits the importance of such study, and that not only must heat, cold, winds, sunshine, ablation, moisture, and precipitation be the causes of variations, but that the history of past seasons and of the snow reservoirs must bear upon more recent change of mass, all which it is absolutely necessary to carry into account to obtain a reliable budget. It is, however, evidently important that the meteorologists should help in our researches, rather than that we should dissipate our energies by studies specially their trade! Let them bear in mind that, as our author well puts it, "La grandeur relative des glaciers est un indice de la variation du climat." He hopes for light to be thrown upon the question of periodicity of climate by comparative glaciology, and pays a very just tribute to the work of Brückner on Klimaschwankungen. Roughly speaking, Switzerland has witnessed three great oscillations in the century.

A few words as to methods. I. The well-known and elaborate system applied to the Rhône glacier is: In September the *tongue* of that glacier is surveyed, and the superficies of the ground left by its retreat. Simultaneously a levelling is executed of lines, always the same, on the surface of the ice; this gives its variations in volume. Lastly, the annual advance is ascertained of points placed each year on the same profiles, which gives variation in flow.

II. The forest officers in Switzerland adopt a simpler plan. In front of glaciers two fixed marks, one on each side of the containing valley, give a measurable base. From this base the distances of certain principal points on the glacier front are measured at the beginning of September (as in the first case), and their position indicated in abscissæ and ordinates. A sketch upon a convenient scale accompanies the officers' reports, and shows variations in length.

III. Photography, applied by M. Joseph Tairraz, of Chamounix. Each year, at the same date—September—a view of the glacier snout is taken from the same point with the same apparatus. A comparison of successive views gives the required history. A series is very instructive, but the difference from one year to another, in the ice-front, is not easily appreciated, whereas views taken at longer intervals show variations clearly.

IV. To this the writer may add that the possession of a box camera and a prismatic compass with clinometer (or, as he himself has practised, of a Casella's Galton pocket altazimuth) enables a survey and photogram to be made simultaneously, simply by placing the fiducial edge of the clinometer against the side of the camera, on a plane table, plotting the compass bearings, and noting the clinometer. In adding details to maps, *prick out* the station and write notes on the back. Also *spot* glass negatives and *prick* films and prints.

MARSHALL HALL.

III.—The Gold Mines of the Rand, being a Description of the Mining Industry of Witwatersrand, South African Republic. By Frederick H. Hatch and J. A. Chalmers. (London: Macmillan and Co., 1895. Price 17*s*.)

THAT a mining district which produces gold to the value of £6,963,000 sterling per annum, and the market value of whose mines is over £100,000,000, should so long remain without any work descriptive of the nature of the industry and the geological structure of the country, is remarkable.

Messrs. Hatch and Chalmers' book on the "Gold Mines of the Rand" will be found to contain a brief description of the geology of the district and a more extended account of the mines, the method of mining employed, and two useful chapters on the metallurgical treatment of the ore, including the history and application of the cyanide process. The work is copiously illustrated and is accompanied with a geological section, two maps of the chief mining centres of the Southern Transvaal, and several tables showing the monthly output of the mines, dividends paid, etc.

The authors have put together, in a very readable form, a mass of information that has been gradually accumulating on the subject.

The chapters on the geology of the district are confined to a brief account of the geological structure of South Africa, a description of the auriferous conglomerates, and some remarks on the nature of the mineralization, the origin of the ore bodies, and the distribution and value of the gold contents.

The South African formations are broadly grouped together in descending order as follows:

Recent deposits.
Karoo formation.
Cape formation.
South African Primary formation.

The Witwatersrand beds (following Schenck) are assigned to the Cape formation, but no new facts are brought forward to support this view.

Some errors that have appeared in nearly all descriptions of the geological structure of the country are repeated. Thus the quartzites and shales to the immediate north of Johannesburg are represented on the diagram section as having the same dip as the auriferous conglomerates, whereas they are only locally conformable, though the strike of the two groups is coincident from east to west. There is little doubt that the junction of the gold-bearing beds and the quartzite shale group is a faulted one, and that the true sequence remains to be discovered.

The relation of the "Banket beds" to the Primary formation is also not clearly stated, but it is inferred (p. 71) that they rest on the eroded edges of the latter. Near Johannesburg and again near Vredefort there is very clear evidence that the Banket beds are pushed over the ancient metamorphic rocks, while there is no evidence to show that the conglomerate beds were formed by the

denudation of the Primary rocks. The metamorphic rocks of the Transvaal consist chiefly of altered igneous rocks, but the conglomerates are composed almost exclusively of quartz-pebbles, without a single specimen of any other kind except sandstones.

It seems certain that the age of the Witwatersrand beds will have to be decided by mineralogical identity. Their relation to the older rocks must not be considered as proved until some mineral that is known to be peculiar to the metamorphic rocks is detected in the matrix of the Banket beds. It is true that in the Zwarteberg Mountains sandstones, with scattered quartz-pebbles similar to those of the "Banket," are folded in with rocks in which Spirifers and Terebratulæ of Carboniferous species are said to occur. But it has been demonstrated again and again how dangerous it is, in a folded district, to argue the age of beds when closely associated or even in actual contact.

The classification of the auriferous conglomerates into a conformable and unconformable set has little geological importance. It is impossible to correlate the conglomerates of outlying districts with those near Johannesburg since there is really no distinctive lithological difference between the various conglomerates. The paltry difference in the size and number of the pebbles is no safe guide. Even if there were a bed or group of beds that could with certainty be recognized throughout the Southern Transvaal as occupying a definite horizon in the auriferous series, it would be extremely difficult, owing to the faulted character of the country and the complexity introduced by the intrusions of igneous masses, to piece together the disjointed fragments that remain.

The igneous rocks are briefly described as basic "greenstones"—diabase, epidiorite, and gabbro being recognized among others.

No attempt is made to classify the faults and dykes according to their relative ages. It is certain that many of the dykes were formed prior to the deformation of the beds, since they have been converted into schistose rocks, while others show no signs of alteration. It is interesting, however, to find that reverse faulting is recognized, which results in some cases in the reduplication of the beds, as instanced on the property of the Witwatersrand Company, where the conglomerates of the Main Reef Series have a double outcrop.

The origin of the gold is left an open question, but no connection is found to exist between the gold contents of the conglomerates and their proximity to igneous masses or dykes.

In the chapter on "Deep Levels" the authors have carefully avoided introducing theory into their descriptions, and make no allowance for the part played by reverse faults in bringing the Main Reef Series nearer to the surface, but it is by no means an impossibility that the members of the Main Reef Series will be found much nearer the surface than any ordinary flattening of the beds could account for.

From the facts brought forward by Messrs. Hatch and Chalmers and other observers, it is certain that in the Rand formation the

geological student has an excellent field for studying the incipient stages of dynamo-thermo-metamorphism. In a work primarily intended for mining students and the general public, it is not to be expected that these subjects will be treated of in more than mere outline, but it is to be hoped that a geologist, who is both a good stratigraphist and petrologist, will attempt to unravel the geology of the country. A careful investigation of the district and a conscientious collection of all the available facts will certainly bring to light much that is new and interesting to geological students, and which would in turn be of much practical value.

REPORTS AND PROCEEDINGS.

Geological Society of London.

November 6th, 1895.—Dr. Henry Woodward, F.R.S., President, in the Chair.

The President announced that the Council had temporarily appointed Mr. Clyde H. Black to the post of Assistant-Clerk.

The following communications were read:—

1. "The Serpentine, Gneissoid, and Hornblendic Rocks of the Lizard District." By T. G. Bonney, D.Sc., LL.D., F.R.S., F.G.S., Professor of Geology and Mineralogy in University College, London.

After some introductory remarks the author states that in company with the Rev. E. Hill, and in consequence of their work in Sark, he again investigated the question of the genesis of the hornblende-schists at the Lizard, and was able to overcome the difficulties which formerly withheld him from attributing an igneous origin to the schists themselves and their banded structures to fluxional movements during consolidation. Here also, as in Sark, there is some evidence of this banding being the result, at any rate in places, of a mixture of a less and a more basic material. Additional evidence is given as to the genesis of the granulitic group and its relations to the hornblende-schist. Moreover, in consequence of the paper by Messrs. Fox and Teall, published in the Society's Journal (vol. xlix, p. 199), the author has again examined (with Mr. Hill) every section which he could discover to bear on the relations of the serpentine, the hornblende-schist, and the granulitic rock. A number of instances are quoted where the serpentine splits open or rumples the bands of the granulitic rock, or cuts across them. He shows that in the sections at Potstone Point and elsewhere the serpentine is welded to the hornblende-schist, cuts across its banding, and behaves generally as an intrusive rock, while the rare cases of apparent interstratification of the two prove to be the results of the inclusion and occasionally very local melting down of the latter by the former rock. He maintains that the relations of the serpentine to the granulitic and the hornblendic groups are inexplicable on the hypothesis of an igneous complex, so far as he understands the meaning of that

term, or of a folding in a solid condition or any other form of dynamo-metamorphism, and he maintains his original opinion that the serpentine (*i.e.* the original peridotite) is intrusive in the other rocks.

The paper also deals with some minor points in the geology of the Lizard; the author supplying some additional particulars about the serpentine at Porthkerris and Porthallow, and explaining that he has found the rocks on the south side of Porthoustock Cove to be only a continuation of those which form the crags south of the opening of the Cove, though they are generally less well preserved: namely, a fine-grained gabbro, intrusive in the ordinary Crousa Down gabbro, and "greenstone" dykes cutting both of these.

2. "The 'Schistes Lustrés' of Mont Jovet (Savoy)." By J. W. Gregory, D.Sc., F.G.S.

The author gives a history of the controversy as to the age of the 'schistes lustrés' of the Western Alps, making special reference to the views of Zaccagna and Bertrand concerning the schists of Mont Jovet. Of these writers, the former maintains that the rocks of the summit of the mountain are old rocks on which the Carboniferous and Triassic strata were deposited unconformably; while, according to the latter author, the rocks forming the top of the mountain were laid down after those which flank it.

In the present paper the author gives the results of an examination of the rocks of Mont Jovet recently made by him. He contends that Lory and Zaccagna were correct in identifying the central rocks of Mont Jovet as 'schistes lustrés,' for this conclusion is supported by their lithological characters and the occurrence of basic igneous rocks of the 'pietre-verdi' type associated with them, and is not opposed to their stratigraphical relations. It is further maintained, as the result of the evidence collected by the author, that the schists in question are older than the Trias; for fragments of the schists occur in the Trias, there is a discordance of strike between the two series, masses of dolomite rest unconformably upon the flanks of the schists, and the Trias has escaped metamorphism which the schists have undergone. The probabilities are in favour of the schists occupying the same relation to the Carboniferous as they do to the Trias; while the close approximation of the schists to the former shows that the schists are not the altered representatives of the neighbouring Carboniferous beds, and it is therefore concluded that the 'schistes lustrés' are pre-Carboniferous, but evidence by which finally to assign them to any exact horizon before this date is still wanting.

CORRESPONDENCE.

ON THE USE OF THE TERM *BOLDÉRIEN*.

Sir,—Will you allow me a few words on the term *Boldérien* as applied in the abstract of the interesting paper of Mr. G. F. Dollfus (Geol. Mag., October 1895, p. 474) on the seas during Upper

Tertiary times in Western Europe. This name was originated by Dumont for the white sands, without fossils, which appear in the Bolderberg, near Hassalt. We can observe these sands, in places, on the banks of the Rhine, where they contain fossils, and are classed as Upper Oligocene. The Miocene of Belgium is the *Crag noir d'Anvers*, part of the *Diestien* of Dumont, the *Anversien* of Cogels and Van Ertborn.

Lately, M. E. Van den Broeck has endeavoured to demonstrate on the evidence of fossils found in the upper beds of the *Boldérien* at Waenrode, that the *Boldérien* and *Anversien* are *synonymous*, and, consequently, that the term *Anversien*, being newer, must be cancelled. This view, it appears, was adopted by M. Dollfus; but I still maintain that this correlation is by no means well founded, and agree with Cogels and others that our ancient *Boldérien* is Oligocene.

Université de Liége;
October 29th, 1895.

C. Dewalque.

OBITUARY.

DR. ERNST VON REBEUR-PASCHWITZ.

Born August 9th, 1861. Died October 1st, 1895.

Dr. Ernst von Rebeur-Paschwitz was born on August 9th, 1861, at Frankfurt a. Oden. In consequence of his father's movements as a Government officer, Von Rebeur's school was often changed, but wherever he went his knowledge of mathematics made him in these studies *facile princeps*. He obtained his doctorate at Berlin, where he became an assistant at the Observatory. At Karlsruhe, where he was 'Erster Assistant,' he commenced, in 1884, to interest himself in Zöllner's pendulum. It was about this time that his health first caused anxiety to his friends. Although he visited Switzerland, Italy, Teneriffe, and other places, returning to his home in apparently good health, it was soon recognized that his recoveries were only temporary. At Halle, where he was Privat Docent, the condition of his throat and chest precluded him from giving lectures. From 1891 until his death, on October 1st, 1895, he was more or less confined to a bed or sofa, often suffering excruciating pain, and never left his room excepting during the summer.

It was during this period of physical incapacity that Von Rebeur produced his most remarkable work, and became the pioneer of a new seismology. Commencing with the endeavour to measure lunar gravitation, he discovered the diurnal wave, that earthquakes could be recorded at stations distant more than a quarter of the earth's circumference from their origin, came in contact with the ubiquitous tremors, and observed many other phenomena connected with the movements of our so-called *terra firma*. These discoveries attracted the attention of other observers, and horizontal pendulums were established at several of the more important observatories in Germany and Russia.

Von Rebeur's last work was an endeavour to obtain co-operation for the observation of these instruments throughout the world, a scheme which, although he has not lived to realize it, will, in all probability, be accomplished in the near future. His ability and energy are testified by the works he leaves behind, and his modesty and kindly nature are spoken of by all who knew him. J. M.

Captain Charles Tyler, F.L.S., F.G.S., whose death on the 2nd November last, in his 70th year, we deeply regret to record, was for very many years an active member of the Council of the Palæontographical Society, and keenly interested in all microscopical research. He also worked assiduously at the Protozoa with the late Dr. Bowerbank, F.R.S.

MISCELLANEOUS.

A most useful "Bibliography of Midland Glaciology" has been contributed by Mr. W. J. Harrison to the Proceedings of the Birmingham Natural History and Philosophical Society (vol. ix, 1895). His record includes the titles of more than one hundred and fifty papers, dating from the year 1811 up to the present time, and written specially on the Drift deposits or glacial phenomena of the Midland counties; and he has added titles of over a hundred other books and papers which have a more general bearing on the subject. Nor has he confined his record to titles, for notes are given on the contents of nearly every article. He remarks that singularly little attention was paid to the Midland Drift by the officers of the Geological Survey when they mapped the region in 1855–60. What is now wanted is a detailed survey of the various accumulations of Boulder-clay, Sand, and Gravel.

"The Onyx Marbles: their origin, composition, and uses, both ancient and modern," is the title of a Memoir by Mr. George P. Merrill (1895. Reprinted from the Report of the United States National Museum). The term onyx marble, as is well known, is applied to varieties of travertine or stalagmite, which exhibit banding and translucency that are often as pronounced as in the true onyx. Used in ancient times for various ornamental purposes, and known as "Oriental alabaster," the marble has been obtained in Persia, Egypt, Algeria, Italy, Mexico, California, Arizona, and other regions; and it is largely used for interior decoration at the present day. Mr. Merrill enters fully into the characters of the several onyx marbles, and to their method of formation by springs in the open and in caverns. His work is illustrated by 18 plates.

Erratum.—In Dr. Gerhard Holm's article, November Number, line 21 from top of page 482: after the word "canal," insert a full stop (.); then for "which," read *What*; and in line 22, for "consisting" read *consists*.

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